

The 2021 Western North America heatwave was a rare and unprecedented compound weather event, that broke century-old temperature records by as much as 9°F. While there is little doubt that anthropogenic global warming contributed to the probability and magnitude of the extreme temperatures, the uniqueness of the event challenges quantifying this influence by traditional event attribution methods.

Van Oldenborgh et al. (2022) summarize the challenges of attributing heat waves.

<https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2021EF002271>

A warming climate means that a fixed temperature threshold is passed more often, and hence the probability of extreme heat increases. However, land use changes, vegetation change, irrigation, air pollution, and other changes also drive local and regional trends in heatwaves. Sometimes these factors enhance heatwave intensity, but they can also counteract the effects of climate change. Temperature variability is unrealistic in many climate models, and can fail standard quality checks. Therefore, reliable attribution of heatwaves remains a major scientific challenge in many regions, particularly where the moisture budget is not well simulated, and where land surface changes, changes in short-lived forcings, and soil moisture interactions are important.

6.4.2 Case study – Hurricane Harvey rainfall ~~IDONT LOVE THIS EXAMPLE. DELETE? MAYBE SOMETHING ELSE?~~

Hurricane Harvey made landfall in southern Texas on August 24, 2017 as a Category 4 hurricane. The primary damage from Harvey occurred after the storm had been downgraded to a tropical storm and stalled near the coastline with a stationary front along the TX/LA border, dropping torrential and unprecedented amounts of rainfall over Texas. Hurricane Harvey provides an informative example of the challenges of detection for a rare event, and also the complexity of extraneous factors that can influence such an event.

The first issue to consider is detection. Harvey set the record for most amount of rainfall from a continental U.S. landfalling hurricane (60 inches), going back at least to the 1880's when comprehensive records begin (Landsea, 2017). The previous top four rainfall producers for U.S. landfalling hurricanes were: Tropical Storm Amelia (1978) with 48 inches in Texas, Hurricane Easy (1950) with 45 inches in Florida, Tropical Storm Claudette (1979) with 45 inches in Florida, and Tropical Storm Allison (2001) with 40 inches in Texas. Looking more broadly at North American hurricanes that made landfall in Central American and the Caribbean, Roth (2017) identifies the following landfalling hurricanes that produced more rainfall than Harvey: 100 inches in Cuba from Hurricane Flora (1963), 96 inches in Jamaica from the November 1909 Hurricane, 63 inches in Nicaragua from Hurricane Mitch (1998), and 62 inches in Mexico from Hurricane Wilma (2005). Hurricane Harvey's rainfall arguably meets the detection criteria, whereby an attribution analysis is justified, although Harvey's rainfall was far from unprecedented from historic Atlantic hurricane landfalls.

In addressing the attribution of extreme rainfall from a landfalling hurricanes, there are several factors leading to excessive rainfall that aren't associated with temperature. Slow motion of the hurricane near landfall can lead to high amounts of local rainfall (e.g. Wilma – 2005; Harvey – 2017;). Mountains/hills near the coast magnify rainfall potential due to forced upslope flow (e.g. Mitch – 1998). Upper-level troughs and cold fronts can lead to excessive rainfall (e.g. Floyd – 1999). Horizontally large tropical cyclones have larger rain footprints, which can lead to excessive rainfall owing to the longer time frame over which rainfall falls at any one location.

The WWA attribution analysis of Hurricane Harvey's rainfall (Oldenburgh et al., 2017) found that human-caused climate change made the heavy rainfall associated with Hurricane Harvey roughly three times more likely and 15% more intense.

<https://iopscience.iop.org/article/10.1088/1748-9326/aa9ef2#:~:text=This%20would%20indicate%20that%20the,to%20Houston's%20flood%20protectio n%20system.&text=Author%20to%20whom%20any%20correspondence%20should%20be%20addressed>

Several publications based on model simulations have concluded that as much as 40% of the rainfall from Hurricane Harvey was caused by human-caused global warming (Emanuel 2017; Risser and Wehner 2017). The rationale for these assessments was that prior to the beginning of summer of 2017, sea surface temperatures in the western Gulf of Mexico exceeded 86 °F and ocean heat content was the highest on record in the Gulf of Mexico (Trenberth et al. 2017). However, El Niño–Southern Oscillation (ENSO) and Atlantic circulation patterns contributed to this elevated heat content.

Landsea (2017) summarizes the arguments for more rainfall from tropical cyclones traveling over a warmer ocean. Simple thermodynamic calculations suggest that the amount of rainfall in the tropical latitudes would increase by about 4% per °F of sea surface temperature increase. Examining a 300 mile radius circle for nearly all of the rain implies that about 10% more total hurricane rainfall for a warming of 2-2.5 °F. The Gulf of Mexico has warmed about 0.7 °F since 1960. Even if it is assumed that all of this warming is due to manmade global warming suggests that roughly 3% of hurricane rainfall today can be reasonably attributed to manmade global warming. Hence, only about 2 inches of Hurricane Harvey's peak amount of 60 inches can be linked to manmade global warming.

Aryal et al. (2018) examined the contribution of North Atlantic hurricanes to flooding and heavy rainfall across the continental U.S. Their analysis does not point to any significant changes in the magnitude or frequency of floods. They found that the North Atlantic Oscillation (NAO) plays a significant role in hurricane-related extreme rainfall along the U.S. East Coast, while ENSO is most strongly linked to the hurricane-related precipitation in Texas.

With regards to the rainfall associated with landfalling hurricanes, there is no clear signal of increasing rainfall owing to the complexity of the factors contributing to hurricane-induced rainfall.

6.5 Summary

There is an ongoing scientific debate around attribution methods, particularly in attributing extreme weather events to climate change. The IPCC has long cautioned that methods to establish causality in climate science are inherently uncertain and ultimately depend on expert judgement.

There are two areas of substantive criticism of the IPCC assessment of the causes of the recent warming: inadequate assessment of natural climate variability, and inappropriate statistical methods.

Detection of extreme weather events is challenged by their rarity, requiring a long data set and a choice of region and spatial scale to evaluate their occurrence against the background of natural weather and climate variability.

The most robust attribution statements for an extreme event relate to an incremental change (e.g. a temperature change or percent change in rainfall). Statements related to return times, quantitative changes in event magnitude and frequency, and probability of the extremes are not accurate and are made with low confidence. There is no evidence in a change of weather or climate regime patterns from increasing greenhouse gases that would amplify or dampen extreme weather events.

From: Judith Curry [curry.judith@gmail.com]
Sent: 5/2/2025 6:42:21 PM
To: Steven Koonin [steven.koonin@gmail.com]
CC: Roy Spencer [roywspencer@hotmail.com]; Ross McKittrick [ross.mckittrick@gmail.com]; Travis Fisher [travis.scott.fisher@gmail.com]; John Christy [climateman60@gmail.com]
Subject: Re: my suggested edits of 4
Attachments: 4.AnthropogenicRF.Apr29 [SEK] JC.docx

My comments on ch 4 are attached, I have some major issues:

Some of what is in this section (esp solar, aerosols) belongs either in climate sensitivity or attribution chapter, not the radiative forcing chapter. (note: my attribution chapter is finished, just sorting out the references). The key aerosol radiative forcing issue (aerosol indirect effect) is not even mentioned.

One possible solution to the aerosol issue is a separate chapter, that includes the impact of recent sulfate rules for ship emissions (there are actually many topics for such a chapter). I could take this on

I object to the Zacharias (2014) and the quote, attributing motives to climate scientists. This would be a very bad look for us

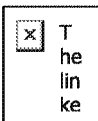
I also think that most of the direct quotes shouldn't be included. These should be reserved for IPCC conclusions or something particularly profound: we don't want to include quotes that come across like "skeptics trying to score cheap points by quoting other skeptics"

On Fri, May 2, 2025 at 10:53 AM Steven Koonin <steven.koonin@gmail.com> wrote:

See attached. Now on to 5!

SEK

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4 Human influences on the climate

4.1 Components of radiative forcing and their history

4.1.1 Historical radiative forcing

A changing climate has been the norm throughout the Earth's 4.6-billion-year history. The Earth's temperature and weather patterns change naturally over timescales ranging from decades to millions of years. Natural variations in the surface climate originate in two ways. Internal climate fluctuations associated with circulations in the atmosphere and ocean produce exchanges of energy, water, and carbon between the atmosphere, oceans, land, and ice. External influences on the climate system include variations in the energy received from the sun and the effects of volcanic eruptions. Human activities influence climate through changing land use and land cover. Humans are also changing the composition of the atmosphere by increasing emissions of CO₂ and other greenhouse gases and by altering the concentrations of aerosol particles in the atmosphere.

The earth is warmed by the sunlight it absorbs and cooled by the radiative heat it emits to outer space. Averaged over Earth, each of these processes involve power flows of about 240 Watts per square meter (W/m²). When they are in balance, there are no net external causes of warming or cooling. Human (and some natural) influences on the climate alter this balance and so cause the climate to change.

Influences on the energy balance are quantified by “radiative forcing”, the extent to which they disturb the warming/cooling balance; a positive forcing warms while a negative forcing cools. The IPCC's estimated history of major components of radiative forcing since 1750 is shown in the following two figures from the IPCC AR6.

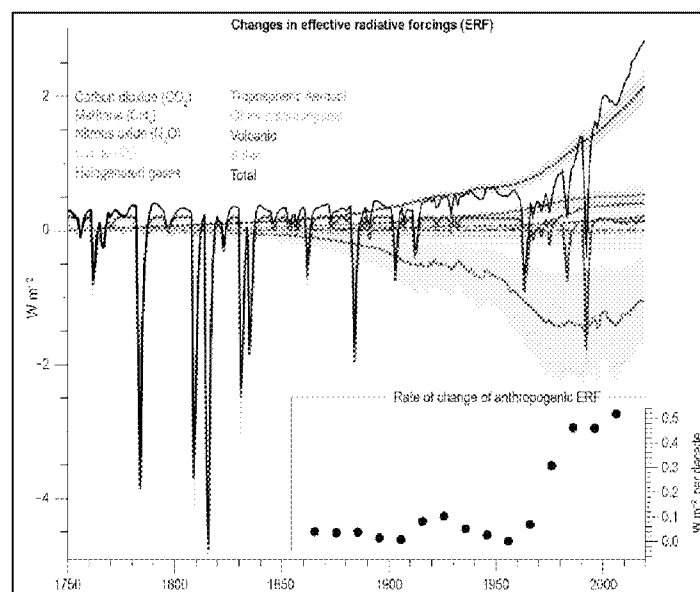


Figure 4.1.1: IPCC estimates of radiative forcing components over time. Source: <https://www.ipcc.ch/report/ar6/wg1/figures/chapter-2/figure-2-10/>

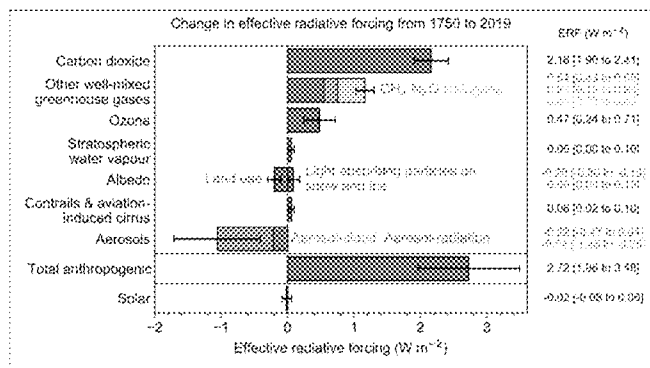


Figure 4.1.2 IPCC estimates of radiative forcing component changes from 1750 to 2019. Source: <https://www.ipcc.ch/report/ar6/wg1/figures/chapter-7/figure-7-6/>

These graphs show that the total radiative forcing is comprised of natural and anthropogenic components. Carbon dioxide is the largest human influence on the climate and the one most relevant to the effects of energy-using systems like motor vehicles. It exerts a warming influence by decreasing the cooling power of the atmosphere. Emissions of CO₂ are accumulating in the atmosphere, as described in the following section, so that the warming influence is increasing. Other greenhouse gases (methane, nitrous oxide, halogens, and ozone), which act similarly, currently add another 75% to CO₂'s warming. Aerosols exert a cooling effect, although with large uncertainties in the way they catalyze the formation of reflective clouds. As a result, understanding of the causes of recent warming requires not just identifying the warming effects of CO₂, but also the more uncertain cooling effects of sulfate aerosols.

IS THIS PARA MORE RELEVANT TO RADIATIVE FORCING OR TO ATTRIBUTION CHAPTER The IPCC views the role of the sun as negligible, based on their preference for reconstructions that imply minimal solar change since preindustrial times. Connolly *et al.* (2021) reviewed sixteen different Total Solar Irradiance (TSI) reconstructions in the literature covering the 1600-2000 interval; they vary from almost no change in TSI to a relatively large upward trend. Connolly *et al.* point out that the variation in TSI reconstructions combined with variations in surface temperature reconstructions implies pairings can be found that are consistent with either no or most 20th century warming being attributable to the sun. A particularly thorny issue is the gap in the TSI data between 1989 and 1991 due to a delay in the launch of a monitor after the Space Shuttle Challenger disaster on January 28 1986, which prevented a replacement satellite from being launched in time to overlap with, and its readings to be intercalibrated with, the prior system

(Zacharias 2014, Scafetta et al. 2019). The question of whether there is an upward trend in TSI over 1978 to 2018 comes down to how the missing data in that gap are filled. ~~That being the case it is noteworthy that Zacharias (2014) observes the solar research community has been motivated by a desire to downplay any potential role of the sun in climate change so as not to detract from arguments for greenhouse gas abatement:~~ THIS IS DUPLICATIVE OF SOME OF THE MATERIAL I HAVE IN THE ATTRIBUTION CHAPTER.

~~A conclusive TSI time series is not only desirable from the perspective of the scientific community, but also when considering the rising interest of the public in questions related to climate change issues, thus preventing climate skeptics from taking advantage of these discrepancies within the TSI community by, e.g., putting forth a presumed solar effect as an excuse for inaction on anthropogenic warming.~~

~~(Zacharias 2014)~~

I'M NOT THRILLED WITH THE ZACHARIAS REF THIS SEEMS LIKE CHEAP POINTS SCORING, AND ATTRIBUTING MOTIVES TO OTHER PEOPLE IS A BAD MOVE. I THINK THE STATEMENT FROM CONNOLLY IS BETTER:

Connolly et al. (2023) found that the Sun/climate debate is an issue where the IPCC's consensus statements were prematurely achieved through the suppression of dissenting scientific opinions.

The other natural forcing component is largely volcanic aerosols, which exert an episodic cooling influence.

The anthropogenic forcing component was negligible before about 1900 and has increased steadily since, rising to almost 3 W/m² today. However, this is still only about 1 percent of the unperturbed radiation flows, making it a challenge to isolate the effects of anthropogenic forcing since state-of-the-art satellite estimates of global radiative energy flows are only accurate to a few W/m². Natural sources of global energy imbalance other than volcanoes are not included in these graphs because they remain largely unknown.

4.1.2 Future radiative forcing

Carbon dioxide's warming influence depends upon how much "extra" CO₂ accumulates in the atmosphere- i.e., its concentration. The CO₂ level as recorded at the Mauna Loa observatory in Hawaii is generally used as the representative global average concentration. The data are

available online at <https://gml.noaa.gov/ccgg/trends/index.html>. The concentration was about 316 ppm at the start of the record in 1959 and is now about 425 ppm, a 34 percent increase.

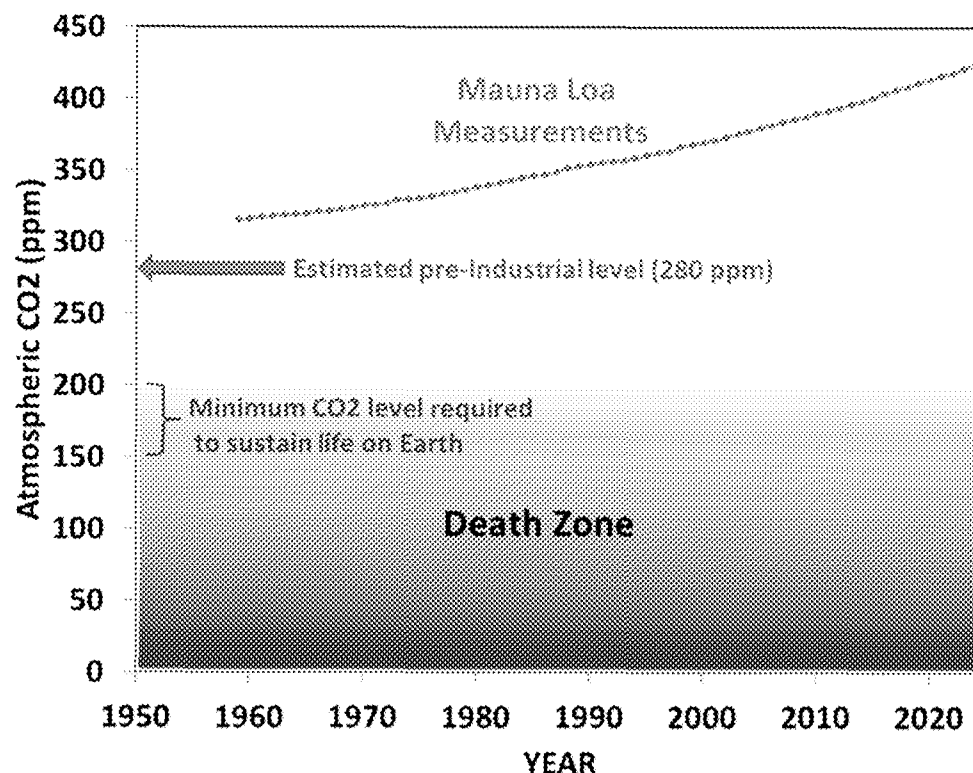


Fig. 4.1.3 Yearly average atmospheric CO₂ concentrations (1959-2024) measured at Mauna Loa, HI (green) compared to the estimated pre-Industrial CO₂ concentration of 280 ppm, and the estimated minimum levels required to sustain life on Earth (150 to 200 ppm). Need source

The annual increase in concentration is only about half of the CO₂ emitted because land and ocean processes absorb “excess” CO₂ at a rate approximately 50% of human emissions. Thus, future concentrations, and hence future human influences on the climate, depend upon two components: (1) future rates of global human CO₂ emissions, and (2) how fast the land and ocean remove extra CO₂ from the atmosphere. We discuss each of these in turn.

4.2 Future emission scenarios and the carbon cycle

4.2.1 Emission scenarios

Assessing the future dangers of GHG emissions requires assumptions about what those emissions will be. Future emissions, and hence human influences on the climate, will depend upon future demographics, economic progress, regulation, and the energy and agricultural technologies in use. Various assumptions about each of those lead to projections of greenhouse gas emissions and concentrations, aerosol concentrations, and changes in land use, which ultimately can be combined into assumptions about anthropogenic radiative forcing.

Because of the great uncertainties about these many factors in the the decades to come, instead of making precise predictions of future concentrations, the IPCC has created various sets of scenarios meant to span a plausible range of possibilities for population, economy, technology, and so on. Recent versions of the scenarios are labeled by a number indicating the anthropogenic radiative forcing expected in 2100 under that scenario. Thus, a scenario labeled with a “6” corresponds to 6 W/m² of human-induced radiative forcing (warming) at the end of the century. (Recall current anthropogenic radiative forcing is about 2.7 W/m².)

Although the IPCC does not put its emission scenarios forward as forecasts they are often treated as such. Comparisons of past scenario groups against observations shows a tendency for IPCC emission projections to overstate actual subsequent emissions. For the IPCC Third and Fourth Assessment Reports a set of emission projections from the *Special Report on Emission Scenarios* were used and hence were referred to as the SREP scenarios. McKittrick *et al.* (2012) showed that, when converted to per capita terms, the SREP scenario distribution was skewed upwards and incompatible with observed trends. McKittrick and Wood (2013) further showed that global energy market dynamics constrained global per capita CO₂ emissions to an extent not reflected in IPCC scenarios. The bias of the SRES scenarios was confirmed by the later analysis in Hausfather *et al.* (2019) who showed that observed atmospheric CO₂ concentrations tracked the low end of the SRES range.

For the Fifth Assessment Report the IPCC developed a new set of scenarios called the Representative Concentration Pathways (RCP). These were identified by a number representing the increase in forcing and were thus called RCP2.6, RCP4.5, RCP6.0 and RCP8.5. RCP2.6 (implying a radiative forcing in 2100 of 2.6 W/m²) projects a GHG concentration pathway leading to warming well below 2 C. At the other end of the scale RCP8.5 is an extreme outcome implying nearly 5 C warming just in this century.

RCP8.5 came to be referred to as the no-policy baseline, or “business-as-usual” scenario in both the academic literature and popular media. It was therefore used to generate the reference outcome supposedly representing the 21st century world in the absence of emission reduction policies. But RCP8.5 was intended as a low-probability high emissions scenario and its usage as a

business-as-usual baseline has been criticized as grossly misleading.¹ Hausfather and Peters (2020) writing in a commentary in *Nature* magazine, pointed out that RCP8.5 was developed as an extreme worst-case, and its misuse as a “business as usual” baseline has resulted in a large number of misleading studies and media reporting:

RCP8.5 was intended to explore an unlikely high-risk future. But it has been widely used by some experts, policymakers and the media as something else entirely: as a likely ‘business as usual’ outcome. A sizeable portion of the literature on climate impacts refers to RCP8.5 as business as usual, implying that it is probable in the absence of stringent climate mitigation. The media then often amplifies this message, sometimes without communicating the nuances. This results in further confusion regarding probable emissions outcomes, because many climate researchers are not familiar with the details of these scenarios in the energy-modelling literature.

(Hausfather and Peters 2020)

The implausibility of the RCP8.5 scenario was examined by Burgess *et al.* (2021). They noted that RCP8.5 has already diverged from observed energy use trends, and the near future trends diverge sharply from those of the International Energy Agency (IEA) which provides market-based projections of energy use for coming decades. IEA trends are based on plausible extrapolations of current economic and demographic trends, and the results run below the entire envelope of RCP projections, implying not only that RCP8.5 is dubious, but even lower emission scenarios are looking unlikely. Burgess *et al.* comment (p. 8):

Beyond 2040, if the trends anticipated by energy agency forecasts continue, carbon intensity will continue diverging from AR5 and SSP baselines—especially from higher-emission scenarios such as RCP8.5, due to the assumptions about fossil-fuel expansion in these scenarios that are increasingly implausible.

Widespread use of RCP8.5 has created an alarmist bias in the climate impacts literature. The extent of this problem was confirmed in a literature analysis by Pielke Jr. and Ritchie (2020). They found (p. 32) that some 16,800 scientific papers published between 2010 and 2020 used the RCP8.5 scenario, with about 4,500 of the articles (p. 16) linking RCP8.5 with the concept of “business-as-usual”. Their analysis showed how RCP8.5 was misused not only by individual researchers, but also by influential science agencies like the IPCC and the US National Climate Assessment (USNCA), which has directly led to misleading coverage in prominent media outlets. They offer the following example (p. 30):

¹ This extreme scenario is useful for modelers, since a large forcing generates a large response (warming) making it easier to assess a model’s sensitivity. But that’s very different than claiming it is a plausible future.

The USNCA employed RCP8.5 as a baseline scenario, despite warning against such use, and compared it to RCP4.5 throughout its report to generate quantitative economic estimates of the benefits of mitigation. In a front-page story, the *New York Times* promoted the report's misuse of RCP8.5 as a baseline scenario:

"A major scientific report issued by 13 federal agencies on Friday presents the starkest warnings to date of the consequences of climate change for the United States, predicting that if significant steps are not taken to rein in global warming, the damage will knock as much as 10 percent off the size of the American economy by century's end."

Pielke and Ritchie (2020) reported new studies using RCP8.5 were appearing in the literature at a rate of about 20 per day, with about two per day specifically linking RCP8.5 and "business as usual." They conclude (p. 34) that the climate research community has spent a decade "committing scientific resources to science fiction" (emphasis added):

"Derived estimates from RCP8.5 as "business as usual" such as future climate impacts, the impacts avoided from mitigation and the cost effectiveness and benefits of mitigation have no real-world meaning... **The scientific literature has become imbalanced in an apocalyptic direction.**

(Pielke Jr. and Ritchie p. 34)

The IPCC later converted the RCP scenarios to the "Shared Socioeconomic Pathway" or SSP scenarios, but these have continued the pattern of bias shown with the RCP and SRES scenarios. Figure 3.1.4 was generated using the Resources for the Future Global Energy Outlook tool (RFF 2025). The black line shows total global observed CO₂ emissions compiled by the International Energy Agency (IEA). The solid green line is the emission trajectory developed by BP Energy taking account of current emission control policies and global energy use outlooks. It overlaps a solid black line which represents the emission projection from the IEA also taking account of energy use projections and current policies. The dashed lines show the range of IPCC SSP policies. As of 2023 global CO₂ emissions have been tracking well below the SSP scenarios especially the two highest ones (SSP5-8.5 and SSP3-7.0).

Carbon dioxide emissions (Million metric tons), by Outlooks & Scenarios. Filtered by Region: World; Fuel: All; Outlook: 2023 Shell (Sky 2050).

Source: RFF Global Energy Outlook at www.rff.org/geo

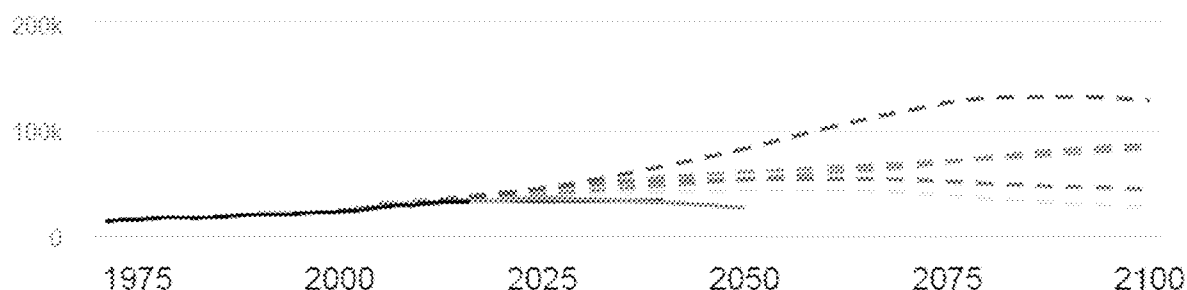


Figure 4.2.1. Observed and projected CO₂ emissions. Source: RFF (2025).

4.2.2 The carbon cycle relating emissions and concentrations

Global carbon cycle models relate concentrations to emissions using estimates of various land and ocean processes that remove CO₂ from, and emit CO₂ into, the atmosphere. Our understanding of these processes was reviewed by Crisp et al. (2021). The natural fluxes of CO₂ in and out of the Earth's surface are very large, many times anthropogenic emissions, but those CO₂ sources and sinks were assumed to be in approximate balance in pre-Industrial times, as evidenced by relatively constant levels of atmospheric CO₂ in centuries past derived from air bubbles in ice cores. This is one of several reasons why increasing atmospheric CO₂ levels are believed to be dominated by anthropogenic sources.

Specifically, fossil fuel burning (and to a lesser extent land use [biomass burning] and cement production) has led to steadily increasing CO₂ levels in the atmosphere, as shown in Fig. 1.2.1. CO₂ emissions from fossil fuel burning is a small fraction of the natural carbon cycle components. About 44,000 Gigatonnes of carbon-equivalent (GtC) are stored in the atmosphere and oceans, mostly in the form of CO₂. (Ciais et al. 2013). Between 150 and 200 GtC are released naturally each year through oceanic outgassing and land-based processes like plant decay and animal respiration. A variable but roughly equivalent amount is absorbed each year by the land and oceans, with a small net loss from the atmosphere because the formation of deep ocean sediment sequesters some carbon permanently. Global fossil fuel consumption and cement manufacture released about 10.3 GtC in 2023, up from 6.2 GtC in 1990 (Ritchie et al.

2024). Of this, about half is naturally sequestered through plant growth and oceanic uptake while the remainder, about half, adds to the atmospheric stock (Ciais et al. 2013).

As noted, each year natural processes remove a net amount of CO₂ equivalent to about 50% of global emissions. Thus, anthropogenic CO₂ emissions average twice what is required to explain the atmospheric rise in CO₂ concentration. The near-constancy of that 50% fraction (the “airborne fraction”) also means that the more CO₂ humanity produces, the faster Nature removes it from the atmosphere. That 50% fraction changes somewhat from year to year due to natural carbon cycle imbalances from El Nino, La Nina, and varying weather patterns. There was also a substantial additional reduction in atmospheric CO₂ after the 1991 eruption of Mt. Pinatubo, a curious result that has yet to be explained (Angert et al., 2004).

The main processes which remove excess CO₂ from the atmosphere are increased production of land vegetation (especially at high latitudes), some increase in the sequestering of carbon in soils, and uptake of CO₂ by the ocean due to the increasing partial pressure of atmospheric CO₂ over that of CO₂ dissolved in the ocean. All twenty land carbon cycle models tracked by the Global Carbon Project (Friedlingstein et al., 2024) show land processes have been removing excess CO₂ at an increasing rate since 1959. This is consistent with a “global greening” phenomenon observed by satellites since monitoring of global greenness began in the 1982. This greening has been traced to CO₂ fertilization and greater drought tolerance of plants exposed to elevated CO₂ levels. While there had been some uncertainty whether a greening trend continued beyond 2000, the most recent research (Chen et al., 2023) has shown continued greening, with even some slight acceleration since 2000. Global greening is discussed further in Section 3.1.

While land vegetation has been responding positively to more atmospheric CO₂, uptake of extra CO₂ by ocean biological processes remains too uncertain to be reliably measured. Our current understanding of these and many more carbon cycle processes was reviewed by Crisp et al. (2021).

Public policy can only change the rate of emissions, not the concentration in the atmosphere. For criteria air contaminants the rate and concentration are closely connected because the lifetime is short and the concentration is small. When emissions are reduced the local pollution concentration drops rapidly, usually on a time scale of a few days. Not so with the global average CO₂ concentration since global carbon cycle is vast and slow. A change in local emissions today will only have a very small global effect, and only after a long time lag. After a pulse (release) of CO₂ emissions to the atmosphere only about 40 percent ($\pm 15\%$) of the extra CO₂ will have been sequestered after twenty years. After a thousand years about 75 percent ($\pm 10\%$) will have been sequestered, and the remainder will gradually be removed over the ensuing tens of thousands of years (Ciais et al. 2013, pp. 472-473). Consequently US CO₂ emission reductions will take decades or centuries to lead to a reduction in the global CO₂ concentration.

To reduce the atmospheric stock of CO₂, assuming the entire increase is anthropogenic, would require emissions to fall below the natural sequestration rate. Since that rate has been averaging about 50% of emissions, a reduction of global emissions by 50% would (at least temporarily) halt the rise in atmospheric CO₂. The 1997 Kyoto Protocol proposed to cap industrial nations' CO₂ emissions at a modest five percent below 1990 levels by the year 2012. Even though this policy ended up being too costly for most nations to implement, full compliance would not have substantially reduced atmospheric CO₂ levels. It would only have slightly slowed CO₂ growth, reaching the projected 2100 level in 2105 instead (Wigley 1998). Similarly, Lomborg (2016) used the widely-used MAGICC climate model and showed that full compliance with the Paris Accord would not stop warming, it would only prevent about 0.1C warming and delay hitting the baseline year 2100 temperature levels by about a decade.

Thus, in contrast with conventional air pollution control, local actions yield extremely small local effects, and only after a long time lag. The practice of referring to unilateral US reductions as "combatting climate change" or "taking action on climate" reflects a profound misunderstanding of the scale of the issue. The scale problem is compounded by recognizing that US motor vehicles account only for about 4 percent of global CO₂ emissions so even a fifty percent reduction in those emissions would have a vanishingly small effect on the global climate.

4.3 Aerosols and the uncertainties associated with them

The role of this chapter should be to address radiative forcing – not ECS or warming attribution. I think that the material in this section should be moved to ECS or attribution. There is huge uncertainty in the aerosol indirect effect, which relates directly to radiative forcing. I can write up something on this

THIS PARA SHOULD BE DELETED HERE, THIS IS COVERED IN THE ATTRIBUTION CHAPTER The climate's sensitivity to CO₂ (as quantified by ECS, the Equilibrium Climate Sensitivity²) is uncertain in part because the anthropogenic radiative forcing is ~~uncertain because the net forcing~~ results from (at least) two counteracting components: warming from GHG's and cooling from aerosols. The observed warming can therefore be made to be consistent with a wide range of pairs of these forces. In the following schematic, the net warming represented by the red

² ECS is formally defined as the increase in equilibrium global average surface temperature resulting from a doubling of the atmospheric CO₂ concentration above its pre-industrial value of 280 ppm. Estimates of ECS are reviewed in Section XX.

arrow could be due to the High GHG warming/strong aerosol cooling pair, or the Low GHG warming/weak aerosol cooling pair, or something in between.

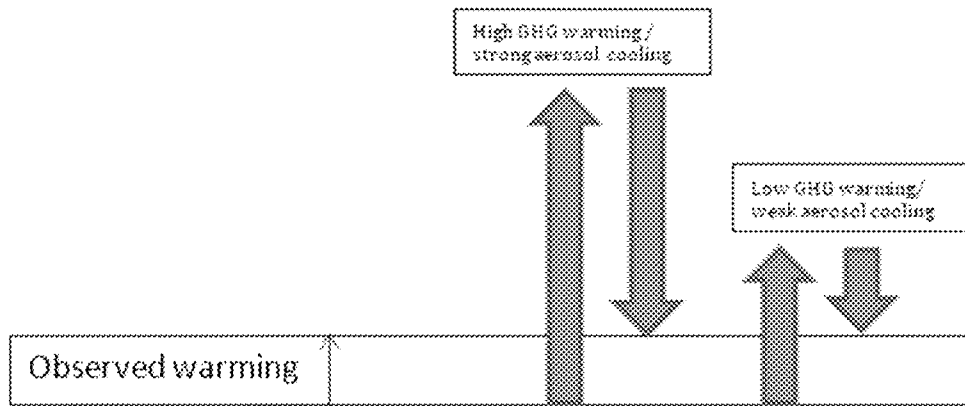


Figure 4.3.1: High and low climate sensitivity to GHGs can be reconciled with the same warming by assuming an offsetting aerosol cooling effect.

THIS CAN GO IN ECS CHAPTER Research on the strength of aerosol cooling is therefore central to more precise ECS estimates. Lewis and Curry (2018) note that after the IPCC AR5 was published in 2013, eleven studies appeared in the scientific literature all finding that aerosol cooling was weaker than had previously been conjectured. Combining the updated aerosol estimates with greenhouse gas, ocean heat uptake and atmospheric warming data from the IPCC and applying standard empirical methods, Lewis and Curry (2018) estimated the best-guess ECS to be 1.66°C with a 95 percent uncertainty range of 1.15 °C – 2.7°C. They concluded that based on the ECS values derived from most IPCC climate models were incompatible with observed data.

There has been further evidence of lower aerosol cooling (implying lower ECS) such as Liu et al. (2021). THIS COULD BE MADE TO BE RELEVANT TO RADIATIVE FORCING CHAPTER These authors tested the hypothesis that aerosols from wildfires has increased since before the 20th century which, if true, would mean there had to have been relatively strong CO₂ warming over that period offsetting the aerosol cooling. They examined soot layers in ice cores extracted from Antarctica and South America and determined that wildfire activity prior to the 20th century was higher than previously believed. Instead of wildfire activity rising steadily from the 1700s to the present, it was high all the time, thus contradicting the hypothesized aerosol cooling trend in

the Southern Hemisphere during the 20th century. They pointed out how this finding relates to the climate sensitivity issue:

Accurate estimates of aerosol radiative forcing are also crucial for better understanding the transient climate response (TCR) and equilibrium climate sensitivity (ECS) to increasing CO₂ and more accurate projection of future climate change. The negative aerosol radiative forcing can, in part, cancel out the positive forcing of increasing greenhouse gases and contribute to the uncertainty of total radiative forcing. An overly large aerosol cooling implies that models might overestimate TCR and ECS to reproduce historical temperature response. A recent study using one of the latest-generation CMIP6 climate models (E3SM) suggested that reducing both the magnitudes of negative aerosol radiative forcing and climate sensitivity yields a better agreement with the observed historical record of the surface temperature.

(Liu et al. 2021)

~~Liu told the UK Daily Mail³~~

~~Climate scientists have known that the most recent generation of climate models have been over-estimating surface temperature sensitivity to greenhouse gasses, but we haven't known why or by how much. This research offers a possible explanation.~~

I really think we should limit direct quotes to IPCC or other official docs, or something that is especially profound.

More evidence pointing to weak aerosol cooling was reported by Wang *et al.* (2021). They noted that the strength of aerosol cooling is partly mediated by cloud behavior and differs between the North and South Hemispheres because of the different density of aerosol emissions. This allowed them to construct another test of climate model validity, which came out in favor of low ECS models. In their words:

Since anthropogenic aerosols primarily concentrate in the Northern Hemisphere, strong aerosol-cloud interaction models produce an interhemispheric asymmetric warming. We show that the observed warming asymmetry during the mid to late 20th century is more consistent with low ECS (weak aerosol indirect effect) models. PARAPHRASE, DIRECT QUOTE NOT NEEDED

Wang et al. (2021)

³ Available online at <https://www.dailymail.co.uk/sciencetech/article-9629919/Climate-change-warming-effect-greenhouse-gases-overestimated-ice-core-study-suggests.html>

THIS PARA IS AN ATTRIBUTION STATEMENT, NOT A FORCING STATEMENT To summarize, quantifying warming due to CO₂ requires understanding the strength of aerosol cooling. While that latter is uncertain a substantial body of recent evidence points to it being relatively weak, implying that CO₂ warming is likewise weak.

Summary

- The global climate is naturally variable. Anthropogenic CO₂ emissions add to that variability by changing the total radiative balance in the atmosphere.
- The IPCC has downplayed the role of the sun in climate change but there are Total Solar Irradiance reconstructions that imply it might have been important, and the modern record is uncertain due to an interruption in satellite coverage.
- Projections of anthropogenic emissions are combined with carbon cycle model estimates of atmospheric CO₂ removal to estimate future CO₂ concentrations and hence the radiative forcings. These are input to climate models to estimate future anthropogenic changes in the climate.
- IPCC emission scenarios envelopes have tended to exceed observed trends.
- The vast majority of academic climate “impacts” studies in recent years are based upon the extreme RCP8.5 scenario that is considered implausible; its usage as a business-as-usual scenario is misleading.
- Despite ample evidence that scenario envelopes are exaggerated, and despite criticism of this practice in the peer-reviewed literature, the IPCC’s most recent scenario set (SSP) perpetuates this malpractice.
- The global carbon cycle heavily dampens the effect of changes in local (e.g. U.S.) CO₂ emissions. Even global-scale emission reductions will have only small, much delayed effects.
- ~~Knowing the magnitude of CO₂ warming requires knowing the strength of aerosol cooling. While that is uncertain, a substantial body of recent evidence points to it being relatively weak, implying CO₂ warming is likewise weak. THIS IS AN ATTRIBUTION STATEMENT~~

Scaffeta, Nicola, Richard C. Willson, Jae N. Lee and Dong Wu (2019) Modeling Quiet Solar Luminosity Variability from TSI Satellite Measurements and Proxy Models during 1980–2018. *Remote Sensing* 11(21) 2569 <https://doi.org/10.3390/rs11212569>

Connolly, Roman, Willie Soon, Michael Connolly et al. (2021) How much has the Sun influenced Northern Hemisphere temperature trends? An ongoing debate *Research in Astronomy and Astrophysics* 21(6) doi: 10.1088/1674-4527/21/6/131 <https://iopscience.iop.org/article/10.1088/1674-4527/21/6/131>

Zacharias, Pia (2014) An Independent Review of Existing Total Solar Irradiance Records. *Surveys in Geophysics* 35 pp. 897—912 <https://link.springer.com/article/10.1007/s10712-014-9294-y>

Liu, Pengfei et al. (2021) “Improved estimates of preindustrial biomass burning reduce the magnitude of aerosol climate forcing in the Southern Hemisphere” *Science Advances* 7(22) May 2021 <https://doi.org/10.1126/sciadv.abc1379>

Wang, C., Soden, B. J., Yang, W., & Vecchi, G. A. (2021). Compensation between cloud feedback and aerosol-cloud interaction in CMIP6 models. *Geophysical Research Letters*, 48, e2020GL091024. <https://doi.org/10.1029/2020GL091024>

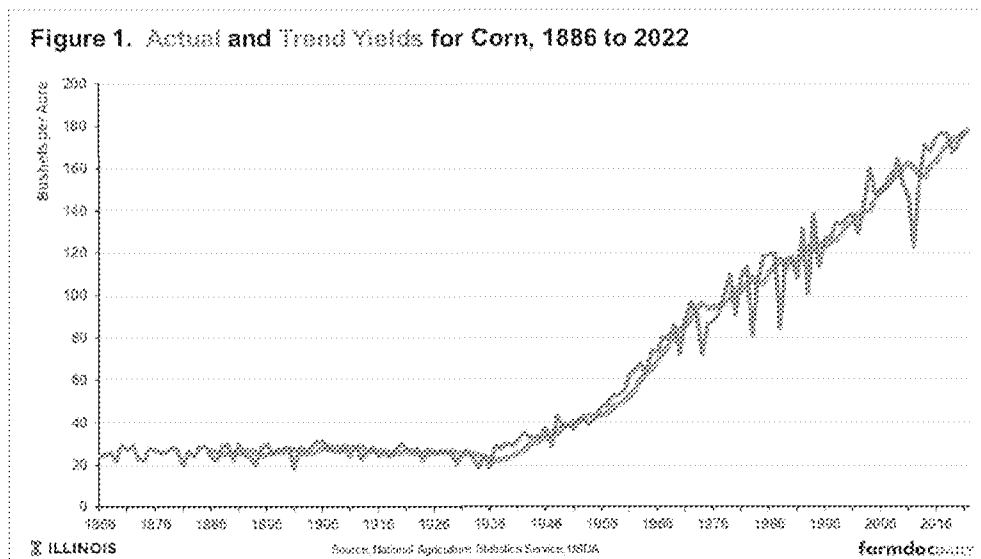
From: Roy Spencer <roywspencer@hotmail.com>
Sent: Tuesday, May 6, 2025 11:41 AM
To: Steven Koonin; 'Judith Curry'
Cc: 'Ross McKittrick'; 'John Christy'; 'Travis Fisher'
Subject: Re: My suggested edits of Chapter 10

For 10 years I gave the keynote talks at the PRXGeo Spring Meetings in Kansas City (PRXGeo, also called "ProExporters" are the leading experts in advising global grain markets). They always talk about yield departures from "trend" (mostly due to weather), but the upward trend is always expected. They consider it mostly to be due to improved farming practices and better seed varieties (the "technological" trend), but I would remind them that increasing CO2 is also involved. Separating the influences, however, is not easy.
-Roy

From: Steven Koonin <steven.koonin@gmail.com>
Sent: Tuesday, May 6, 2025 10:10 AM
To: 'Judith Curry' <curry.judith@gmail.com>
Cc: 'Ross McKittrick' <ross.mckittrick@gmail.com>; 'John Christy' <climateman60@gmail.com>; 'Roy W. Spencer' <roywspencer@hotmail.com>; 'Travis Fisher' <travis.scott.fisher@gmail.com>
Subject: RE: My suggested edits of Chapter 10

Suggest we include one figure like the following (from <https://farmdocdaily.illinois.edu/2022/07/perspectives-on-national-u-s-corn-yields-for-productivity-and-down-side-yield-risk.html>) the beginning of this section. Always good to have something eye-catching to lead off with.

SEK



From: Judith Curry <curry.judith@gmail.com>
Sent: Tuesday, May 6, 2025 10:25 AM
To: Steven Koonin <steven.koonin@gmail.com>
Cc: Ross McKittrick <ross.mckittrick@gmail.com>; John Christy <climateman60@gmail.com>; Roy W. Spencer

<roywspencer@hotmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>

Subject: Re: My suggested edits of Chapter 10

My comments on ch 10 are attached

On Tue, May 6, 2025 at 7:03 AM Steven Koonin <steven.koonin@gmail.com> wrote:

See attached.

SEK

--



Judith Curry, President
CFAN - Climate Forecast Applications Network
Reno, NV USA
curry.judith@cfanclimate.com | +1.404.803.2012
<http://www.cfanclimate.net>

From: Judith Curry [curry.judith@gmail.com]
Sent: 5/6/2025 3:51:30 PM
To: Steven Koonin [steven.koonin@gmail.com]
CC: Roy Spencer [roywspencer@hotmail.com]; Ross McKittrick [ross.mckittrick@gmail.com]; John Christy [climatemanager60@gmail.com]; Travis Fisher [travis.scott.fisher@gmail.com]
Subject: Re: My suggested edits of Chapter 10

For ch 10, i prefer to move the crop material from ch 2 to ch 10, and then talk about the confounding factors in attributing yield increases

On Tue, May 6, 2025 at 8:49 AM Steven Koonin <steven.koonin@gmail.com> wrote:

Right. And then there are papers claiming that the trend isn't as large as it might have been because of "climate change". But the claimed decrements are small and, more importantly, there's no way to prove that counterfactual.

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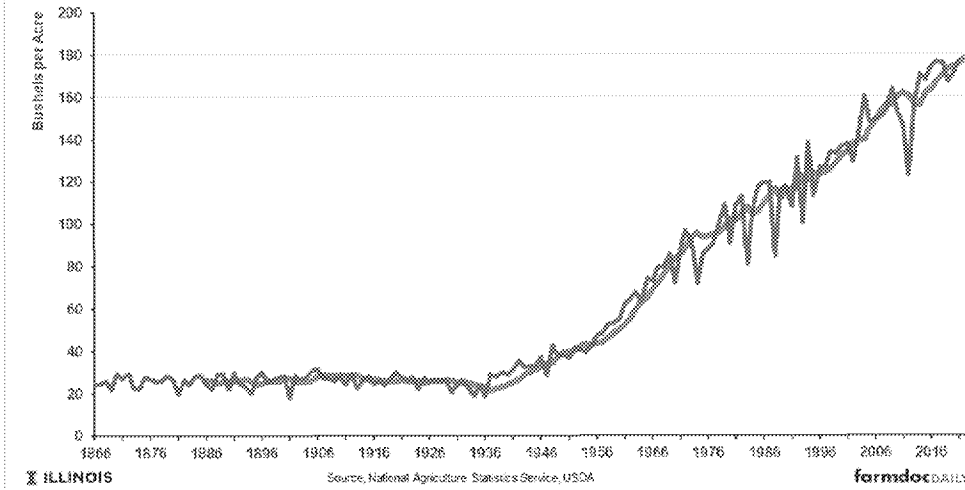
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SEK

Figure 1. Actual and Trend Yields for Corn, 1886 to 2022



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Cc: Ross McKittrick <ross.mckittrick@gmail.com>; John Christy <climateman60@gmail.com>; Roy W. Spencer <roywspencer@hotmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>

Subject: Re: My suggested edits of Chapter 10

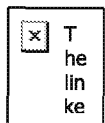
My comments on ch 10 are attached

On Tue, May 6, 2025 at 7:03 AM Steven Koonin <steven.koonin@gmail.com> wrote:

See attached.

SEK

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From: Roy Spencer <roywspencer@hotmail.com>
Sent: Tuesday, May 6, 2025 3:31 PM
To: John Christy; Judith Curry
Cc: Steve Koonin; Ross McKittrick; Travis Fisher
Subject: RE: My suggested edits of Chapter 10

John made a corny joke.

Sent from my Verizon, Samsung Galaxy smartphone

----- Original message -----

From: John Christy <climateman60@gmail.com>
Date: 5/6/25 2:28 PM (GMT-06:00)
To: Judith Curry <curry.judith@gmail.com>
Cc: Steve Koonin <steven.koonin@gmail.com>, Ross McKittrick <ross.mckittrick@gmail.com>, "Roy W. Spencer" <roywspencer@hotmail.com>, Travis Fisher <travis.scott.fisher@gmail.com>
Subject: Re: My suggested edits of Chapter 10

All

It's a-maize-ing that the pessimistic story has held sway for so long.

John C.

John Christy
Director, Earth System Science Center
Professor, Atmos and Earth Science
Alabama State Climatologist
The University of Alabama in Huntsville
climateman60@gmail.com

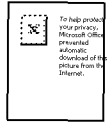
On May 6, 2025, at 9:25 AM, Judith Curry <curry.judith@gmail.com> wrote:

My comments on ch 10 are attached

On Tue, May 6, 2025 at 7:03 AM Steven Koonin <steven.koonin@gmail.com> wrote:

..... See attached.

SEK



To help protect
your privacy,
Outlook Office
prevented
automatic
download of this
picture from the
Internet.

Judith Curry, President
CFAN - Climate Forecast Applications Network
Reno, NV USA
curry.judith@cfanclimate.com | +1.404.803.2012
<http://www.cfanclimate.net>

<10 Climate and Agriculture.May6[SEK] CURRY.docx>

From: Ross McKittrick <ross.mckitrick@gmail.com>
Sent: Tuesday, May 6, 2025 5:46 PM
To: Steven Koonin
Cc: Roy Spencer; John Christy; Judith Curry; Travis Fisher
Subject: Re: My suggested edits of Chapter 10
Attachments: 10 Climate and Agriculture.May6[SEK][Curry][RM].docx

Here's a revision of chapter10. I have improved the opening section by doing a more proper survey of the topic and bringing it up to date. There's a ton of economics literature about CC and agriculture which we'd get slammed for if we don't acknowledge and I think this is a minimum coverage of it. The field has swung back around to fairly optimistic findings. But I also point out that the whole literature has ignored CO2 fertilization, which segues into the next section. I moved the crop-related material out of Ch 2 to here at Judy's suggestion. And put in a nice crop yield chart from NBER. The overall picture is CO2-driven climate change is likely a net nothing for US ag or a net benefit.

On Tue, May 6, 2025 at 3:34 PM Steven Koonin <steven.koonin@gmail.com> wrote:

There's a kernel of truth in that ...

SEK

From: Roy Spencer <roywspencer@hotmail.com>
Sent: Tuesday, May 6, 2025 3:31 PM
To: John Christy <climateman60@gmail.com>; Judith Curry <curry.judith@gmail.com>
Cc: Steve Koonin <steven.koonin@gmail.com>; Ross McKittrick <ross.mckitrick@gmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>
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John Christy

Director, Earth System Science Center

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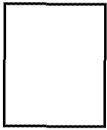
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<10 Climate and Agriculture.May6[SEK] CURRY.docx>

10. Climate change and US agriculture

10.1 Econometric analyses

Econometric analyses of the effects of climate change on agriculture have sought to integrate information about long term crop yield changes in response to temperature and precipitation changes under assumptions about adaptive behavior by farmers. One method focuses on variations in agricultural land values. The rationale is that if climate change is a long-term net benefit for agriculture it should translate into higher market values for agricultural land, and vice versa. While individual crops might benefit from or be harmed by climate change, once the adaptive responses of farmers are taken into account the value of farmland represents an index of whether the changes are expected to be beneficial or not. Mendelsohn et al. (1994) examined the relationship between historical climatic variations on agricultural land values and concluded global warming would be slightly beneficial to American agriculture.

The Mendelsohn et al. method, called Ricardian analysis after David Ricardo, the 19th century British economist who pioneered the study of land values, attracted subsequent criticism from authors who argued it failed to account for differences in land values attributable to fixed locational characteristics like soil quality, and non-climatic changes including nearby urbanization. Deschênes and Greenstone (2007) looked at agricultural profits instead of land values and reached similar conclusions to Mendelsohn et al. (1994), namely that past climatic variations had relatively little effect on farm profitability and that warming would likely yield small overall benefits for the US agricultural sector. However a subsequent exchange with critics led them (Deschênes and Greenstone 2012) to revise their conclusions and project potentially large losses in US agriculture due to climate warming. Burke and Emerick (2016) looked at temperature variations over 1980 to 2000 and argued that farmers were not as able to adapt to temperature changes as the Ricardian method assumes and that climate change would have large negative impacts on corn and soy yields. Schlenker and Roberts (2009) similarly argued that yield gains to past warming would not carry over to the future and corn and soy yields would sharply decrease this century due to climate change.

Two recent studies have argued that pessimistic findings such as these are not robust. Ortiz-Bobea (2019) argued that land values aggregate farm and non-farm influences and the latter need to be filtered out. He developed a data set using cash rents for agricultural activity as a measure of land value specifically for farming activity. Whereas the land value model implied future losses under climate warming, the same model estimated using cash rents did not, leading the author to conclude the pessimistic results were due to using an inaccurate measure of the returns to farming activity. Bareille and Chakir (2023) assembled a large data base on farm sale prices in France for properties that sold twice between 1996 and 2019. They could replicate pessimistic results showing negative effects of warming on agricultural land values using conventional econometric modeling. But by taking advantage of the repeat sales data, which provides information on site-specific changes in land prices, they found the results reversed and implied that climate change will be very beneficial for French agriculture. The authors concluded that, taking adaptation into account, a warming climate would yield positive benefits for French agriculture that were between two and 20 times larger than had previously been estimated. On average, with full adaptation, they concluded that climate changes under the medium RCP4.5 scenario could double the value of French farmland by 2100.

A major deficiency of all these studies, however, is that they omit the role of CO₂ fertilization. Climate change as it relates to this report is caused by GHG emissions, chiefly CO₂. The econometric analyses referenced above focus only on temperature and precipitation changes and do not take account of the beneficial growth effect of the additional CO₂ that drives them. As explained in Chapter 2 CO₂ is a

major driver of plant growth so this omission biases the analysis towards underestimation of the benefits of climate change on agriculture.

10.2 Field studies of CO₂ enrichment

One of the ways the effect of CO₂ on crop growth has been studied is through “free air enrichment experiment” or FACE plots, in which small chimneys are placed in fields surrounding plants and the growth response to elevated CO₂ under varying weather conditions are recorded. Ainsworth et al. (2020) summarizes results from about 250 such studies. They found that elevation of CO₂ by 200 ppm cause an average 18% increase in crop yield in C3 plants. C4 plants exhibited benefits mainly under drought conditions.

In addition to FACE plot experiments there have been thousands of laboratory experiments on the effects of CO₂ on all kinds of plant growth. Here we review some of the results on key US agricultural crops.

Soybean

Studies on the impact of elevated CO₂ on Soybean (*Glycine max* (L.) Merr.) plants in the water-deficient region of Huang-Huai-Hai Plain, China, showed that elevated CO₂ concentrations resulted in improved photosynthesis rate, water use efficiency and growth (Li, 2013) under both normal conditions and drought conditions. The CO2Science.org website reports on 108 published experiments between 1985 and 2019 exposing soybean to enriched CO₂ levels. Converted to a +300ppm common scale the average growth benefit was +50.9 percent. In addition there were 10 studies reporting on +600 ppm CO₂ enrichment, resulting in an average increase in photosynthesis of 90.3%.

Maize (corn)

The CO2Science.org website reports on 28 published experiments between 1983 and 2018 exposing corn (*Zea mays* L.) to enriched CO₂ levels. Converted to a +300ppm common scale the average growth benefit was +23.7 percent. Corn also benefits from increased drought tolerance under elevated CO₂. An experimental study (Allen Jr, 2011) exposed plants to water stress conditions in sunlit controlled-environment chambers at 360 ppm (ambient) and 720 ppm (elevated) CO₂. The drought stress caused a 41% loss of growth under ambient CO₂ but only a 13% loss under elevated CO₂.

Wheat

The CO2Science.org website reports on 92 published experiments between 1983 and 2020 exposing common wheat (*Triticum aestivum* L.) to enriched CO₂ levels. Converted to a +300ppm common scale the average growth benefit was +67.6 percent. Blandino (2020) measured the yield as well as nutritional quality of an “improver” hybrid wheat variety and its parents under elevated CO₂ levels (+166 ppm). They reported a grain yield increase of +16% but a 7% decrease in grain protein levels. But they found that the food quality of different wheat varieties responded differently to elevated CO₂ levels, so that with proper varietal selection end-users can select wheat types that best take advantage of the elevated CO₂.

Further evidence

A 2021 report from the US National Bureau of Economic Research (Taylor and Schlenker 2021) used satellite-measured observations of outdoor CO₂ levels across the United States, matched to county-level agricultural output data and other economic variables. After controlling for the effects of weather, pollution and technology the authors concluded that CO₂ emissions had boosted US crop production since 1940 by 50 to 80 percent, attributing much larger gains than had previously been

estimated using FACE experiments. They found that every ppm of increase in CO₂ concentration boosts corn yields by 0.5 percent, soybeans by 0.6 percent, and wheat by 0.8 percent.

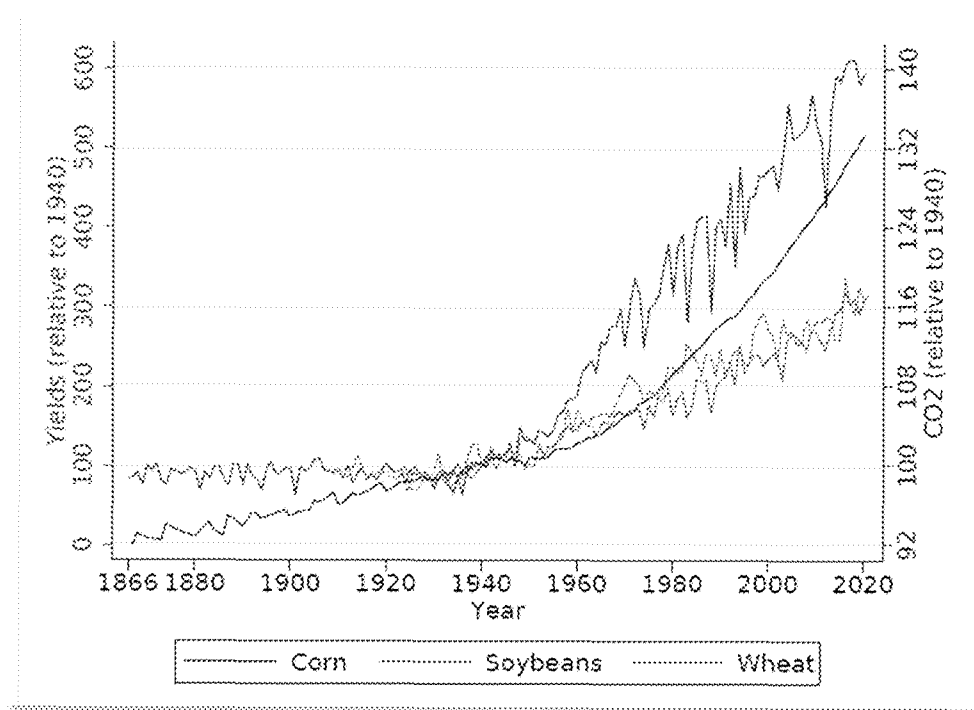


Figure 10.1: US average CO₂ levels and yields of corn, soy and wheat all normalized so 1940=100.
Source: Taylor and Schlenker (2021)

Beyond growth benefits, extra CO₂ boosts plant resilience to heat. Deryng et al. (2016) surveyed all available evidence regarding how wheat, maize, rice and soybean will grow under a combination of climate warming and rising CO₂ levels. They concluded that warming would, eventually, have a negative effect on plant growth but it would be fully compensated by the extra CO₂ for wheat and soybean, and almost fully for rice and maize. And as discussed in Chapter 2, plants use water more efficiently when there is more CO₂ in the air.

Deryng et al. (2016) surveyed evidence on crop water productivity (CWP), i.e. yield per unit of water used, drawing attention to the potential for CO₂ both to enhance photosynthesis and reduce leaf-level transpiration (water loss during leaf respiration). They surveyed all available FACE data on crop yield changes for Maize (corn), Wheat, Rice and Soybean, and combined it with crop model data simulating yield responses as of 2080 under the extreme RCP8.5 scenario in four growing regions (Tropics, Arid, Temperate and Cold) each of which were split into rainfed and irrigated sub-regions. In every region they reported that models without CO₂ fertilization predicted CWP losses but CO₂ fertilization more than offset them and once it was taken into account all regions showed a net CWP gain. Deryng et al (2016) also reported that negative impacts on wheat and soybean yields were fully offset by CWP gains, and mitigated by up to 90% for rice and 60% for maize.

Similar to this, Cheng et al. (2017) noted that increased global plant growth from 1982 to 2011 due to rising CO₂ uptake was accompanied by such large gains in CWP that despite the extra biomass global water use by plants had not increased.

Deryng et al. (2016) assumed that climate change would “exacerbate water scarcity”. It is noteworthy that while models predict drylands will expand under climate warming, current data show the opposite: greening is happening even in arid areas. Zhang et al. (2014) report that due to increased CO₂ levels “increasing aridity in drylands won’t lead to a general loss of vegetation productivity”; increased desertification will happen in at most 4% of currently arid areas.

10.3 Crop modeling meta-analyses

Notwithstanding the abundant evidence for the direct benefits of CO₂ and of CO₂-induced warming on crop growth, in 2023 the US Environmental Protection Agency (EPA 2023) boosted its estimate of the Social Cost of Carbon (SCC) about five-fold based in large part on a very pessimistic 2017 estimate of global agricultural damages from climate warming (Moore et al., 2017). One of the two damage models used by the EPA attributed nearly half of the 2030 SCC to projected global agricultural damages based on the Moore et al. (2017) analysis. This study was a meta-analysis of crop model studies simulating yield changes for agricultural crops under various climate warming scenarios. Moore et al. projected declining global crop yields for all crop types in all regions due to warming.

McKittrick (2025) re-examined the Moore et al. database and found that, while it claimed to cover 1,722 studies, only half the entries ($N=862$) had complete records, so that the sample available for regression analysis was much smaller than both studies indicated. McKittrick noted that the variable most commonly missing was the change in ambient CO₂ and found that in many cases these could be recovered from the underlying studies or the original climate scenario tables. He thereby increased the usable sample size by 40 percent. The crop yield projections incorporating the newly available data changed considerably. As shown in Figure 10.2, whereas the partial data set implied warming would decrease yield (blue lines), the complete data set implied constant or increase global yields, even out to 5°C warming (green lines).

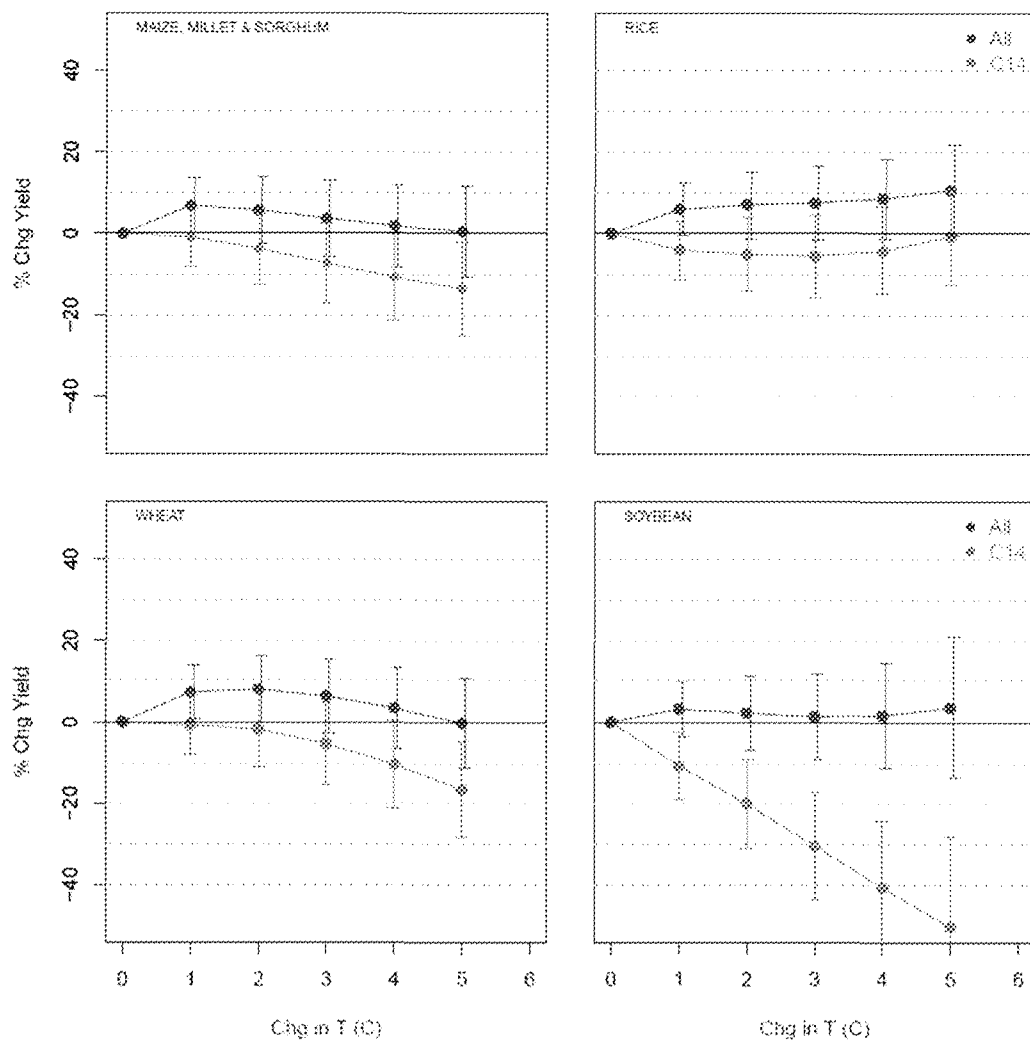


Figure 10.2 Crop yields under CO₂-induced climate warming. Blue: as published in Moore et al. (2017). Green: after including omitted data. Source: McKittrick (2025).

In summary, there is abundant evidence going back decades that rising CO₂ levels benefit plants including agricultural crops, and that CO₂-induced warming will be a net benefit to US agriculture. The warming since 1981, in combination with adaptive behaviour by farmers, has been beneficial on its own for maize. The increased ambient CO₂ has also boosted productivity of all major US crop types. Various attempts to argue that CO₂-induced warming will harm agriculture do not hold up under scrutiny.

Deschênes, Olivier and Michael Greenstone (2007) *The Economic Impacts of Climate Change: Evidence from Agricultural Output and Random Fluctuations in Weather* *American Economic Review*. Feb 2007, Vol. 97, No. 1: Pages 354-385

Deschênes, Olivier and Michael Greenstone (2012) The Economic Impacts of Climate Change: Evidence from Agricultural Output and Random Fluctuations in Weather: Reply to Comment *American Economic Review*. 102, no. 7: 3761-3773. <http://hdl.handle.net/1721.1/82641>

Ortiz-Bobea, Ariel (2019) The role of nonfarm influences in ricardian estimates of climate change impacts on US agriculture. *American Journal of Agricultural Economics*. 102 (3), 934–959.

Schlenker, Wolfram and Michael Roberts (2009) Nonlinear temperature effects indicate severe damages to U.S. crop yields under climate change. *Proceedings of the National Academy of Sciences* 106 (37) 15594-15598 <https://doi.org/10.1073/pnas.0906865106>

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10. Climate change and US agriculture

10.1 Ricardian analysis **CHANGE THE SECTION TITLE TO SOMETHING PEOPLE WILL UNDERSTAND WITHOUT DEFINING THE WORD RICARDIAN**

Scientists have long known about the beneficial effect of CO₂ on plant growth and have studied it extensively. Thousands of experiments in laboratories and outdoor field settings (CO2Science.org, undated) have confirmed beneficial effects for food plants and crops of all kinds from higher CO₂ levels.

Evidence that CO₂-induced warming will be neutral or beneficial for agriculture, particularly in the US, goes back decades. Mendelsohn et al. (1994) examined the effects of historical climatic variations on agricultural land values and concluded “our projections suggest that global warming may be slightly beneficial to American agriculture.” Mendelsohn et al. (2000) provided a global assessment of the impacts of 2°C warming by 2060 (equivalent to 3.3 °C warming per century). They concluded that 2°C warming “will result in net market benefits for most OECD countries”. Tol (2002) published estimates of the global impact on agriculture of a 2.5 degree C warming. Assuming farmers adapt to the changes, he expected every region to end up better off.

DEFINE LAND VALUE ARE YOU JUST TALKING ABOUT AGRICULTURE OR SOMETHING ELSE There have been criticisms of the methodology used by Mendelsohn et al. (1994) to associate land value changes with climate change. It potentially omits other important determinants of land value that change over time **SUCH AS WHAT**, leading some authors to argue that the benefits of warming would be much smaller or even negative. Bareille and Chakir (2023) addressed the criticisms by assembling a large data base on farm sale prices in France for properties that sold twice between 1996 and 2019. By comparing the change in land value on the same farm to local climatic and economic changes they were able to remove the confounding influence of fixed site-specific characteristics and isolate the contribution of climate variables. Those authors concluded that, taking adaptation into account, a warming climate would yield positive benefits for French agriculture that were between two and 20 times larger than had previously been estimated. On average, with full adaptation, climate changes anticipated under the medium RCP4.5 scenario could double the value of French farmland by 2100. They also noted that application of earlier methods to the same data suggests climate change would harm French agriculture.

THE PREVIOUS PARAGRAPHS ARE CONFUSING. I WOULD JUST TALK ABOUT AGRICULTURE AND NOT LAND VALUE, UNLESS YOU DEFINE NON-AG VALUES

10.2 Field studies

As discussed in Chapter 2 **I PREFER TO SEE THIS MATERIAL IN CHAPTER 10 RATHER THAN IN CHAPTER 2**, scientists have used so-called Free Air CO₂ Enrichment, or FACE, experiments to measure how plants in outdoor settings respond to local increases in the concentration of carbon dioxide. In a 2021 study that reviewed 160 FACE experiments conducted over 20 years, Hu *et al.* (2021) concluded that elevated CO₂ levels had boosted rice growth on average by 16 percent. Furthermore, when they looked at hybrid varieties particularly suited to the higher CO₂ levels, growth increased by nearly 25 percent.

Wheat also benefits from CO₂-induced climate change. The website CO2Science.org (http://www.co2science.org/data/plant_growth/photo/t/triticuma.php) reports on 92 published experiments between 1983 and 2020 exposing wheat to enriched CO₂ levels. Converted to a +300 parts per million common scale, the average growth boost was 67.6 percent.

A 2021 report from the US National Bureau of Economic Research (Taylor and Schlenker 2021) used satellite-measured observations of outdoor CO₂ levels across the United States, matched to county-level agricultural output data and other economic variables. After controlling for the effects of weather, pollution and technology the authors concluded that CO₂ emissions had boosted US crop production since 1940 by 50 to 80 percent, attributing much larger gains than had previously been estimated using FACE experiments. They found that every ppm of increase in CO₂ concentration boosts corn yields by 0.5 percent, soybeans by 0.6 percent, and wheat by 0.8 percent.

Beyond growth benefits, extra CO₂ boosts plant resilience to heat. Derying et al. (2016) surveyed all available evidence regarding how wheat, maize, rice and soybean will grow under a combination of climate warming and rising CO₂ levels. ~~DUPLICATIVE OF CH 2, I PREFER THIS MATERIAL IN CH 10~~ They concluded that warming would, eventually, have a negative effect on plant growth but it would be fully compensated by the extra CO₂ for wheat and soybean, and almost fully for rice and maize. And as discussed in Chapter 2, plants use water more efficiently when there is more CO₂ in the air.

Adaption plays a key role in exploiting gains from climate change for US crops. Butler et al. (2018) examined US maize production since 1981 and found that weather changes had been a net benefit. They also found that “current farmer cropping schedules are more beneficial in the climate of the last decade than they would have been in earlier decades” and adaptive responses to warming had added 13 kg per hectare to maize production. They estimated that weather trends since 1981 had boosted US maize production by 28% since 1981.

10.3 Crop modeling meta-analyses

Notwithstanding the abundant evidence for the direct benefits of CO₂ and of CO₂-induced warming on crop growth, in 2023 the US Environmental Protection Agency (EPA 2023) boosted its estimate of the Social Cost of Carbon (SCC) about five-fold based in large part on a very pessimistic 2017 estimate of global agricultural damages from climate warming. One of the two damage models used by the EPA (Moore et al., 2017) attributed nearly half of the 2030 SCC to projected global agricultural damages based on a ~~The EPA used two damage models and in one of them, of the new 2030-SCC value nearly half was attributed to projected global agricultural damages estimated in Moore et al. (2017, denoted M17), which was in turn a reanalysis of a database first presented in Challinor et al. (2014, denoted C14).~~ The Challinor data base was a meta-analysis of crop model studies simulating yield changes for agricultural crops under various climate warming scenarios. ~~M17~~ Moore et al. projected declining global crop yields for all crop types in all regions due to warming.

McKittrick (2025) re-examined the Challinor database and found that, while it claimed to cover 1,722 studies, only half the entries ($N=862$) had complete records, so that the sample available for regression analysis was much smaller than both studies indicated. McKittrick noted that the variable most commonly missing was the change in ambient CO₂ and found that in many cases these could be recovered from the underlying studies or the original climate scenario tables. He thereby increased the usable sample size by 40 percent. The crop yield projections incorporating the newly available data changed considerably. As shown in Figure 10.1, whereas the partial data set implied warming would decrease yield (blue lines), the complete data set implied constant or increase global yields, even out to 5°C warming (green lines).

In summary, there is abundant evidence going back decades that rising CO₂ levels benefit plants including agricultural crops, and that CO₂-induced warming will be a net benefit to US agriculture. The warming since 1981, in combination with adaptive behaviour by farmers, has been beneficial on

its own for maize. The increased ambient CO₂ has also boosted productivity of all major US crop types. Various attempts to argue that CO₂-induced warming will harm agriculture do not hold up under scrutiny.

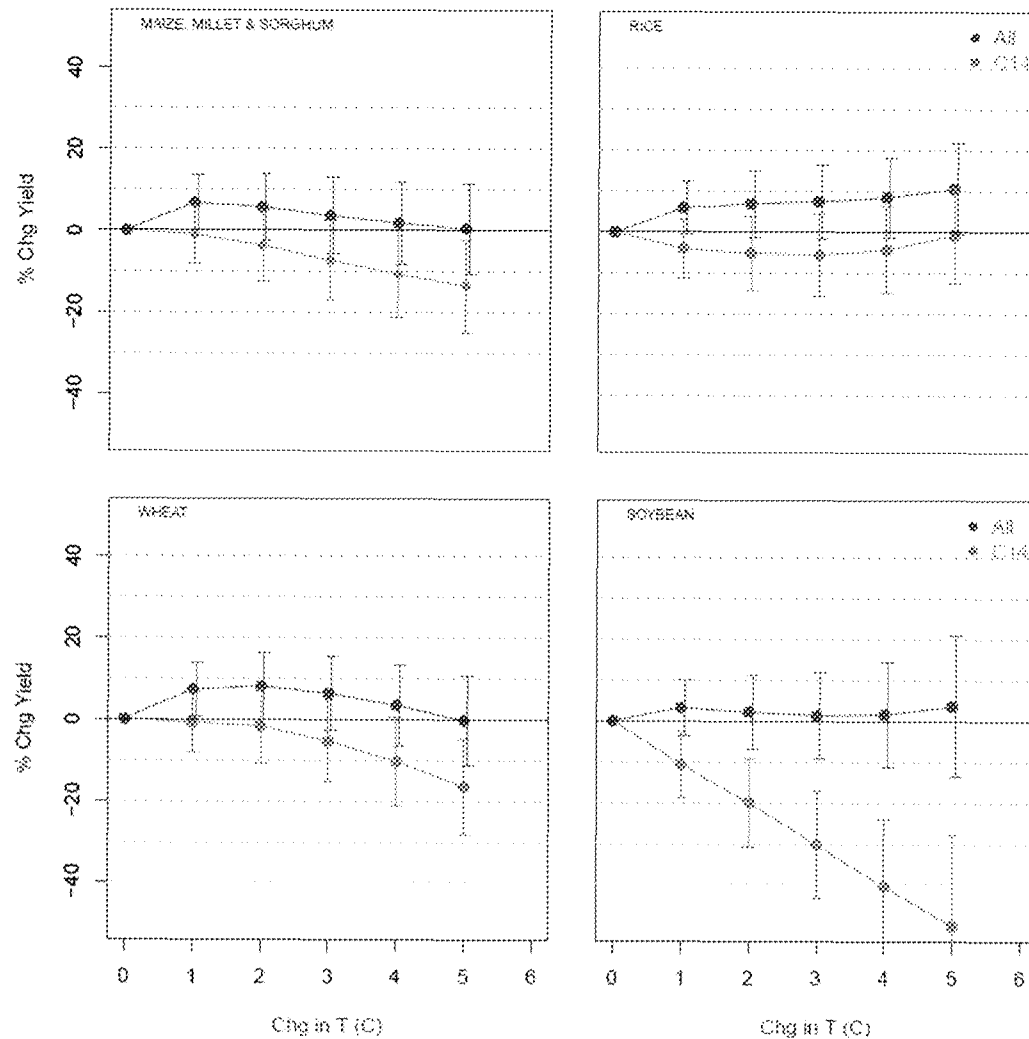


Figure 10.1 Crop yields under CO₂-induced climate warming. Blue: as published in Moore et al. (2017). Green: after including omitted data. Source: McKittrick (2025).

From: John Christy <climateman60@gmail.com>
Sent: Saturday, May 31, 2025 10:26 AM
To: Steve Koonin
Cc: judith curry; Travis Fisher; Roy Spencer; Ross McKittrick; Josh Loucks
Subject: Re: NCA5 editable chapter files

All

Steve: Will you be commenting on the “ratio” of extremes chart from NCA4?

Ross: Figs 2.4 and 2.8:

I’ll finish an Upper Midwest dataset of about 50 stations for daily precipitation this weekend. I now have 31 stations in the Northeast, 29 West Coast, and 24 in Southeast. These can answer questions in Fig. 2.8 NCA5. They have odd metrics - (a) total amount falling on heaviest 1% of days, (b) 1-in-5yr daily max and (c) annual heaviest day. With the datasets I’ll be sending, I think you can produce these values, but I can as well. Note they have no significance attached to any of these that I can tell ... just changes since 1958. So, by explaining how significance is determined for precipitation metrics we will likely show there will always be changes, but their significance is a detail that the NCA5 ignored. Also Fig 21.1 for the Northeast precipitation can be addressed.

Box 4.1: I’ll finish the snowfall time series for the Cascades and the Sierras through the 2024-25 season this weekend and this can address Box 4.1 which showed a recent bad snow year for the west (which shows up in my time series, but so does the big year of 2022-23). You can run the significance values for the trends, but I suspect no significance for the slight rise in snowfall in the Cascades and slight decline in the Sierras since the late 19th century.

Roy: Fig 2.9. I think showing the corn belt trends will shut down this figure - model trends are 50% to 700% too hot already, so projections are not fit-for-purpose.

Judy: Pgs 2-16, 2-17. Will you be addressing the 2021 PacNW heat wave? I imagine you all saw that a woman is suing the oil companies for her mother’s death in a hot car during that event. <https://apnews.com/article/climate-change-oil-greenhouse-gas-emissions-illness-816898178e91d3dd61d87b2d90d34ad5>

Possible pithy saying: "When you can measure what you are speaking about, and express it in numbers, you know something about it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind." William Thomson (Lord Kelvin, 1824-1907)

-or-

“All science is numbers” - Richard Lindzen translation.

John C.

John Christy
Director, Earth System Science Center
Professor, Atmos and Earth Science
Alabama State Climatologist
The University of Alabama in Huntsville
climatemanager60@gmail.com

On May 31, 2025, at 8:02 AM, Steven Koonin <steven.koonin@gmail.com> wrote:

As you might expect, the full NCA5 report is password protected and rather large (214 MB).

To facilitate commenting and editing, I've turned Chapters 1-3 into editable pdfs (unfortunately, BW only and the largest is still some 82 MB). They can be found at this DropBox link:

<https://www.dropbox.com/scl/fo/ppvhdmtmylwevbbvzlkxo3/ADPBkejVUI9OK-sK2taJoJE?rlkey=26crijuou6k7xfoveyo4q258r&st=8b9shpgi&dl=0>

Steve Koonin

From: Travis Fisher [travis.scott.fisher@gmail.com]
Sent: 6/4/2025 5:59:37 PM
To: Josh Loucks [loucksj14@gmail.com]
CC: Steven Koonin [steven.koonin@gmail.com]; Judith Curry [curry.judith@gmail.com]; Roy Spencer [roywspencer@hotmail.com]; cohen.seth1994@gmail.com; Ross McKittrick [ross.mckittrick@gmail.com]; John Christy [climateman60@gmail.com]
Subject: Re: NCA5 preface material

An interesting piece from Roger Pielke Jr, as usual:
<https://open.substack.com/pub/rogerpielkejr/p/what-is-a-worst-case-climate-scenario>

On Wed, Jun 4, 2025 at 1:35 PM Josh Loucks <loucksj14@gmail.com> wrote:

Hi everyone,

I created a Google Drive with all the relevant documents that have been sent (hopefully I included everything, but please add documents if I missed anything).

I have pasted the link below, but it should also appear in your drive under the "shared with me" tab.

If anyone has suggestions or changes that would make y'all's workflow easier, please let me know!

<https://drive.google.com/drive/folders/1Re8Iz10qMZMbFMN7cZK6uAJjHHJcQ7PM?usp=sharing>

Thanks - Josh

On Wed, Jun 4, 2025 at 11:40 AM Steven Koonin <steven.koonin@gmail.com> wrote:

Yes, good to know.

I've also taken material from the prior page (xx, "About This Report") into the accumulating draft.

From: Judith Curry <curry.judith@gmail.com>
Sent: Wednesday, June 4, 2025 11:17 AM
To: Steven Koonin <steven.koonin@gmail.com>
Cc: Travis Fisher <travis.scott.fisher@gmail.com>; Roy Spencer <roywspencer@hotmail.com>; cohen.seth1994@gmail.com; Ross McKittrick <ross.mckittrick@gmail.com>; John Christy <climateman60@gmail.com>; Josh Loucks <loucksj14@gmail.com>
Subject: NCA5 preface material

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On Wed, Jun 4, 2025 at 7:43 AM Steven Koonin <steven.koonin@gmail.com> wrote:

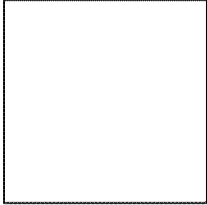
Thanks, Judy. It will fit well into the preamble sections

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cohen.seth1994@gmail.com; Ross McKittrick <ross.mckittrick@gmail.com>; John Christy
<climateman60@gmail.com>; Josh Loucks <loucksj14@gmail.com>
Subject: text for intro

Attached is some text for the intro (not obvious where this would fit in Steve's outline)

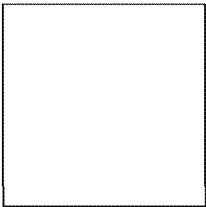
NCAS's Interpretation of its Mission

:



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--
Josh

From: John Christy <climateman60@gmail.com>
Sent: Wednesday, June 4, 2025 6:09 PM
To: Steven Koonin
Cc: Judith Curry; Travis Fisher; Roy Spencer; cohen.seth1994@gmail.com; Ross McKittrick; Josh Loucks
Subject: Re: NCA5 preface material
Attachments: NCA5_daily_precip_JRC_250604.2.docx; NCA5_Heat_Ext_JRC_250604.1.docx

Steve

I've gone through the two pieces I wrote and made statements more clear. The map is also updated with now 61 stations in the upper Midwest.

Note the filename "...250604.X" for these latest versions.

John C.

On Wed, Jun 4, 2025 at 10:40 AM Steven Koonin <steven.koonin@gmail.com> wrote:

Yes, good to know.

I've also taken material from the prior page (xx, "About This Report") into the accumulating draft.

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NCA5's Interpretation of its Mission

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Judith Curry, President

CFAN - Climate Forecast Applications Network

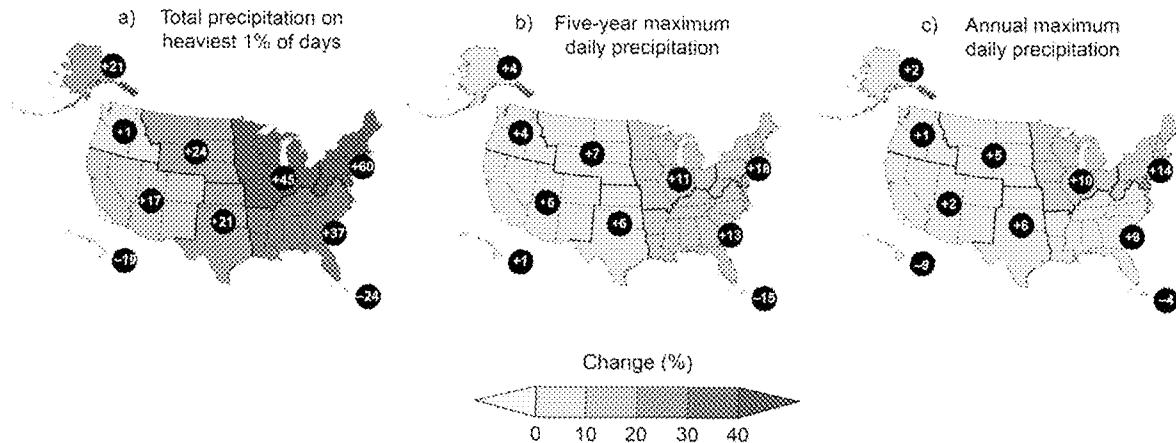
Reno, NV USA

curry.judith@cfanclimate.com | +1.404.803.2012
<http://www.cfanclimate.net>

Discussion of changes in extreme precipitation events in NCA5.

Below is Fig. 2.8 from NCA5 indicating heavy, short-duration precipitation events are becoming more frequent and severe, mainly in the Eastern US.

Observed Changes in the Frequency and Severity of Heavy Precipitation Events



Heavy precipitation events are becoming more frequent and intense across much of the country.

FIGURE 2.8. The frequency and intensity of heavy precipitation events have increased across much of the United States, particularly the eastern part of the continental US, with implications for flood risk and infrastructure planning. Maps show observed changes in three measures of extreme precipitation: (a) total precipitation falling on the heaviest 1% of days, (b) daily maximum precipitation in a 5-year period, and (c) the annual heaviest daily precipitation amount over 1958–2021. Numbers in black circles depict percent changes at the regional level. Data were not available for the US-Affiliated Pacific Islands and the US Virgin Islands. Figure credits: (a) adapted from Easterling et al. 2017;¹²⁶ (b, c) NOAA NCEI and CIRES NCAR.

The NCA5 concludes from this evidence and citing two papers from model studies,

There is robust evidence that human-caused warming has contributed to increases in the frequency and severity of the heaviest precipitation events across nearly 70% of the US.^{126,127}

A scientific examination of this claim would have considered the following questions among many,

- (1) Why do the analyses begin with 1958 when measurements are available from the late 19th century?
- (2) Given that hydrologic/precipitation events are subject to “Long-Term Persistence” (LTP) where long dry- and wet-spells are common features, is it likely such changes are examples of natural variability for any 64-year period? Are these percentage changes significant?
- (3) Were the climate model simulations subjected to independent evaluation before concluding that they represent not only basic climate variations, but precipitation processes accurately enough to allow someone to conclude that human emissions contributed to the changes?

The Diffenbaugh et al. 2018 citation [126] used a short observational window of 1961-2005 to determine “historical” trends, then analyzed output from the implausible RCP8.5 climate model simulations to claim changes were likely human-caused. [See “BOX: Perils of short data records” Ch6 DoE-CWG 2025].

The Kirchmeier-Young 2020 citation [127] utilized observations for only 1961-2010. The model output again was taken from the implausible RCP8.5 simulations. The model output then had to be multiplied by “scaling factors” to force agreement with the magnitudes of historical observations of extreme events. Furthermore, the focus of the analysis was on the CanESM2 CMIP-6 model, one that produced global atmospheric temperature trends that were a factor of 2.5 too positive compared with observations due to excessive sensitivity to GHG forcing (+0.43 vs. +0.17 °C/decade, 1979-2024).

We note the following deficiencies behind NCA5’s claim (see DoE-CWG Ch4-6 for details on these issues),

- (1) “Historical” results for change-analysis are based on short data periods.
- (2) The emissions scenario employed was the implausible rcp8.5.
- (3) Results are based on overly-sensitive models (ECS up to 5.6 °C).

To understand the character of recent changes against the background of a better-quantified natural variability we constructed continuous daily precipitation datasets for stations within four regions; (1) Pacific Coast (1893ff) where IPCC AR6 suggested an increase in Atmospheric River events had been observed since 1948, and three regions that NCA5 indicates are experiencing increases in short-duration heavy events; (2) Upper Midwest (1893ff), (3) Humid Southeast (1872ff) and (4) Northeast (1888ff). Surprisingly, NCA5 did not perform significance-testing on the alleged changes.

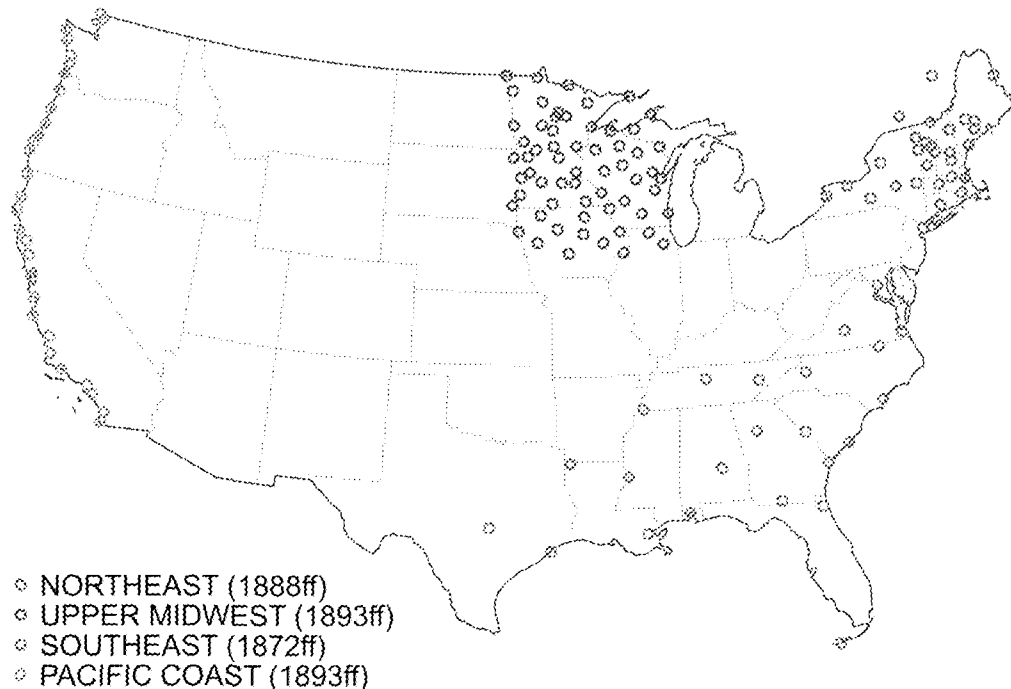


Figure. Location of stations utilized in this study.

Following McKittrick and Christy 2019 (who found no significant changes in the West and Southeast with observations beginning in the late 19th century) we apply the more appropriate statistical analysis which

characterizes LTP for precipitation events to determine if these changes are significant. [The critical importance of incorporating LTP is described in Ch6 of the DoE-CWG 2025.]

When using time series > 130 years the results indicate that while some individual stations have significant positive trends in extreme-event totals and occurrences, regional values do not. Thus, attributing a non-significant change in a phenomenon (increased number of heavy precipitation events) to a specific cause (increased concentrations of GHGs as depicted in poor models with implausible inputs) does not support the NCA5 claim that there is “robust evidence” that human emissions are contributing to changes observed. We conclude that the NCA5 methods and conclusions do not meet the very basic standards of scientific analysis.

Diffenbaugh, N.S., D. Singh, and J.S. Mankin, 2018: Unprecedented climate events: Historical changes, aspirational targets, and national commitments. *Science Advances*, **4** (2), 3354. <https://doi.org/10.1126/sciadv.aao3354>

Kirchmeier-Young, M.C. and X. Zhang, 2020: Human influence has intensified extreme precipitation in North America. *Proceedings of the National Academy of Sciences of the United States of America*, **117** (24), 13308–13313. <https://doi.org/10.1073/pnas.1921628117>

There are mixed (and somewhat convoluted) messages in NCA5 regarding the notion that hot extremes are increasing in the CONUS. In summary-claims, using alarming language, i.e., “record-shattering”, attention is drawn to examples in restricted regions in the CONUS or to short, recent time periods. However, the document does occasionally acknowledge the 1930s heatwaves and the overall decline of hot events in the past 100 years. From NCA5 chapter 2,

(Key Message 2.2) Observations show an increase in the severity, extent, and/or frequency of multiple types of extreme events. Heatwaves have become more common and severe in the West since the 1980s (*high confidence*).

The Risk of Temperature Extremes Is Changing

By some measures, the most extreme heatwaves on record in the United States occurred during the Dust Bowl era of the 1930s. ... Several major heatwaves have affected the US since 2018, including a record-shattering event in the Pacific Northwest in 2021. The western US has been particularly affected by extreme heat since the 1980s (Figure 2.7), experiencing a larger increase in days over 95°F, as would be expected given the greater warming in that region relative to the eastern US. By contrast, the number of very hot days has actually decreased across the central and eastern regions due to summer cooling trends in the region (Figure 2.7; Ch. 22). This does not, however, mean the central and eastern US are not affected by heat. The impacts of extreme high temperatures are more severe if such conditions persist for several days, and overall, multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades. Across 50 large US cities, the US Global Change Research Program heatwave indicator (<https://www.globalchange.gov/indicators/heat-waves>) shows that the average number of heatwaves has doubled since the 1980s, and the length of the heatwave season has increased from about 40 days to about 70 days.

Nighttime temperatures are rising faster than daytime temperatures, and the number of nights where the temperature never falls below 70°F is increasing everywhere in the US except the Northern Great Plains (Figure 2.7). The extent of CONUS experiencing hot summer nights is growing at a faster rate than the extent experiencing hot summer days.

The NCA5 focused much of the heat-discussion on the western CONUS, including the Pacific Northwest heatwave of 2021, as well as rising nighttime temperatures. It only briefly mentions the long-term decline in heat extremes in most of the CONUS. While factually correct in a narrow sense, the full revelation of non-alarming facts is not apparent. We also note the convoluted reasoning in the quote above that hot extremes are apparently due to “greater warming” in the region than experienced elsewhere and that declining hot extremes are “due to summer cooling trends”. Since “trends” do not cause changes, one might ask, “What caused the warming *and* cooling trends?”

These heat issues are addressed in Ch6 of the DoE-CWG demonstrating that the range and magnitude of extreme temperatures (10s of degrees) are driven more by the chaotic behavior of natural variability than the small extra forcing from the enhanced concentrations of CO₂. The DoE-CWG conclusion is that both in terms of hot days ($\geq 95^\circ\text{F}$) and number of days in heatwaves, the current decade is experiencing no more than was experienced 100 years ago. For example, in the 30-year period 1925-1954, representing only 23% of the 1899-2024 data record, the CONUS experienced 33% of the total heat wave days. The most recent 30-years experienced 24%, almost exactly that expected by chance. Thus the claim “multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades,” is simply false when beginning in 1899 (Ch6 Fig. 6.3.6 DoE-CWG).

Figure X displays the occurrence of days $\geq 95^{\circ}\text{F}$, showing the increase in the three western regions and declines elsewhere. Additionally, the trends in both heatwave days and hot days are (insignificantly) negative for the CONUS as a whole.

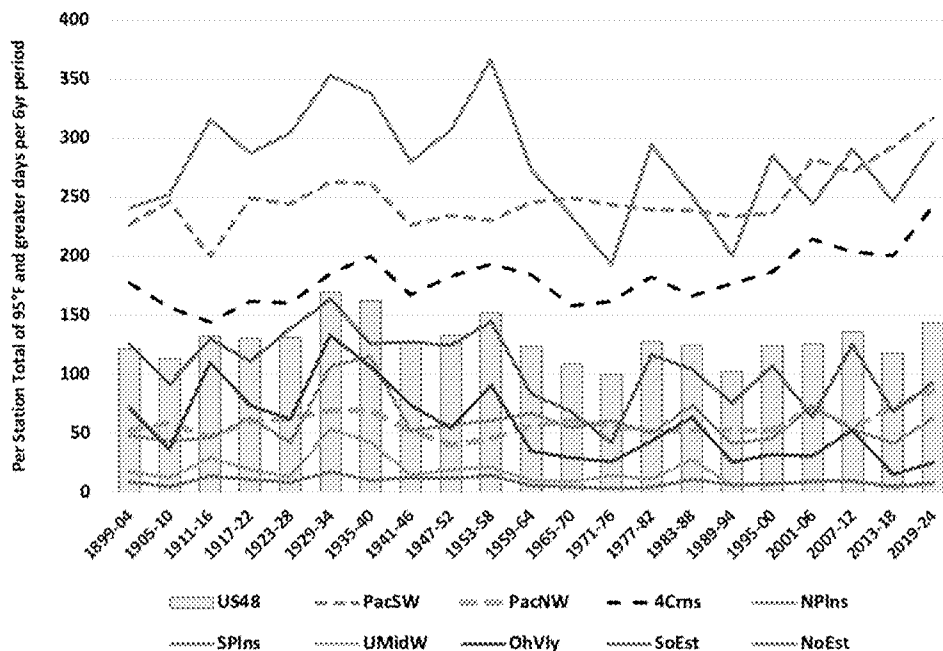


Figure. Number of days $\geq 95^{\circ}\text{F}$ in 6-year periods (1899-2024) for nine CONUS regions (lines, dashed positive trends, solid negative trends) and full CONUS (bars).

The fact (and we agree it is a fact) that summer nighttime temperatures have risen rapidly since 1960 nearly everywhere, and especially in the largest cities, is clear. However, this observation is more a consequence of the urban heat island effect (which has greatest impact on stations changing from rural to semi-rural, Ch6 DoE-CWG) and the choice of starting in the 1960's, the coolest decade since the 1910's.

In attributing claims of rising heat extremes to GHG concentrations, the NCA5 concentrated on the localized 2021 event but is silent on the attribution of declining heat extremes in the eastern 2/3 of the CONUS (the statement "due to summer cooling trends" does not suffice) or the major role that the increasing growth of infrastructure around the stations exerts on nighttime temperatures. The scientific method requires one to demonstrate that a claim must represent all of the evidence, not simply a small portion that agrees with the claim. In this instance the NCA5 falls short of rigorously demonstrating that rising GHG concentrations are responsible for the observed changes (or lack thereof) in hot extremes in the CONUS.

From: Josh Loucks <loucksj14@gmail.com>
Sent: Wednesday, June 4, 2025 1:35 PM
To: Steven Koonin
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Subject: Re: NCA5 preface material

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<http://www.cfanclimate.net>

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Judith Curry, President

CFAN - Climate Forecast Applications Network

Reno, NV USA

curry.judith@cfanclimate.com | +1.404.803.2012
<http://www.cfanclimate.net>

--
Josh

From: Roy Spencer <roywspencer@hotmail.com>
Sent: Monday, July 14, 2025 4:29 PM
To: Steven Koonin
Cc: Judith Curry; Ross McKittrick; John Christy; Travis Fisher; Josh Loucks; Seth Cohen
Subject: RE: NCA5 progress

So, if most authors maintain that $2+2=5$, and we have the temerity to disagree, should we avoid being adversarial? Of course we are adversaries of conventional "wisdom". There is no way to avoid that without sounding squishy. Stand up for what we believe is the proper interpretation of the data.

Sent from my Verizon, Samsung Galaxy smartphone

----- Original message -----

From: Steven Koonin <steven.koonin@gmail.com>
Date: 7/14/25 3:15 PM (GMT-06:00)
To: Roy Spencer <roywspencer@hotmail.com>
Cc: Judith Curry <curry.judith@gmail.com>, Ross McKittrick <ross.mckittrick@gmail.com>, John Christy <climateman60@gmail.com>, Travis Fisher <travis.scott.fisher@gmail.com>, Josh Loucks <loucksj14@gmail.com>, Seth Cohen <seth.cohen@hq.doe.gov>
Subject: Re: NCA5 progress

Yes, of course. Just like school kids, it "believes" what it's been exposed to and can't "think" critically.

So I discount the comments on substance. But do give some credence to its comments on tone and framing.

Steven Koonin

On Jul 14, 2025, at 16:06, Roy Spencer <roywspencer@hotmail.com> wrote:

Isn't it true that AI models are going to survey the *conclusions* of published studies, even if the underlying analyses do not support those conclusions?

Sent from my Verizon, Samsung Galaxy smartphone

----- Original message -----

From: Steven Koonin <steven.koonin@gmail.com>
Date: 7/14/25 1:17 PM (GMT-06:00)
To: 'Judith Curry' <curry.judith@gmail.com>, 'Ross McKittrick' <ross.mckittrick@gmail.com>
Cc: 'John Christy' <climatemanager60@gmail.com>, "'Roy W. Spencer'" <roywspencer@hotmail.com>, 'Travis Fisher' <travis.scott.fisher@gmail.com>, 'Josh Loucks' <loucksj14@gmail.com>, 'Seth Cohen' <seth.cohen@hq.doe.gov>
Subject: RE: NCA5 progress

Here's what COPilot has to say about Judy's desmarked version:

Here's a structured analysis of the **NCA5 Review** document (authored by Judith Curry and colleagues), focusing on four key dimensions: **scientific accuracy**, **tone**, **bias**, and **logical coherence**.

Scientific Accuracy

Strengths

- **Valid critiques of model sensitivity and emissions scenarios:** The report raises legitimate concerns about the plausibility of SSP5-8.5 and excessive reliance on high-end sea level projections. These reflect ongoing debates in the literature and are grounded in methodological caution.
- **Methodological concerns are substantive:**
 - Inconsistencies in time-series analysis and selective baselines (e.g. 1958 vs 1901) are rightly flagged as a statistical pitfall.
 - Emergent constraints critique aligns with studies (e.g. Schlund et al., 2020) that caution against overinterpreting spurious correlations.
- **Challenges attribution simplifications:** Points to cases where NCA5 presents strong attribution claims without robust methodological explanation—particularly on precipitation and heatwaves.

Limitations

- **Some critiques rely on selective counter-literature:** While the report references CWG25 and contrarian scientists (e.g. McKittrick, Christy, Pielke Jr.), it underrepresents the broader consensus literature and fails to engage with rebuttals to those views.
- **Reproduction failures lack detail:** When stating inability to replicate NCA5's findings, such as trends in precipitation, the methodology is referenced but not fully shown—limiting reproducibility of the critique itself.
- **Model criticisms overgeneralized:** Claims that current models are “not fit-for-purpose” for long-term regional projections ignore recent advancements in downscaling, probabilistic framing, and multi-model ensembles.

Tone

- **Formal but adversarial:** The report maintains a professional structure but frequently uses language that characterizes NCA5 as biased, ideological, or propagandistic (e.g., “hyperbolic advocacy,” “activist tone,” “naïve and simplistic”).
- **Occasional rhetorical overreach:** Phrases like “scientific malpractice,” “usurps the public’s right to informed choice,” or citing 1970s-era editorials suggest a broader normative agenda beyond empirical review.
- **Dismissive of policy framing:** The critique is sharply opposed to NCA5’s social justice themes and policy recommendations, labeling them extraneous or political, rather than engaging with their empirical basis (e.g., equity in heat exposure).

Bias and Framing

Category	Indicators
Source Selection	Prioritizes CWG25, skeptics of consensus science; under-cites mainstream climate literature

Category	Indicators
Framing Strategy	Positions CWG25 as scientific corrective to NCA5's alleged ideological bias
Motive Attribution	Suggests mainstream climate scientists are motivated by fear, activism, or political mandates
Language Use	Uses emotionally and politically charged terms in what is framed as a scientific review • Binary worldview: The document tends to frame climate discourse as either “Gold Standard Science” or ideological overreach, leaving limited room for middle-ground scientific pluralism. • Limited acknowledgment of uncertainty in contrarian claims: While NCA5’s uncertainties are dissected in detail, competing claims (e.g., about historical heatwaves or CO₂ fertilization benefits) are presented with stronger rhetorical conviction and minimal caveats.

Logical Coherence

Internal Structure

- Well-organized chapters with clear progression:
 - From systemic critique (e.g., peer review process, overconfidence) to granular examples (e.g., precipitation trends, heatwave framing).
 - Inclusion of references, appendices, and traceability comments reinforces formal review tone.

Coherence Gaps

- **Circular referencing:** The report repeatedly relies on CWG25 to corroborate its claims, creating a loop rather than triangulating with independent peer-reviewed sources.
- **Generalizations from anecdotes:** Statements about young scientists “trying to save the planet” or critiques of NCA5’s cover image veer into editorial territory and dilute the analytical focus.
- **Recommendations blend science and policy ideology:** Calls to rewrite the Global Change Research Act or eliminate regional climate projections are rooted more in philosophical disagreement than scientific infeasibility.

Summary Judgment

Dimension	Verdict
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Scientific Accuracy	Substantive methodological critiques, selective evidence base
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Tone	Adversarial and rhetorically charged
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Bias and Framing	Heavy reliance on contrarian sources; limited engagement with consensus science
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Logical Coherence	Structured and readable, but occasionally editorial and circular
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This is a technically informed but ideologically framed critique. It raises valid concerns about uncertainty treatment, scenario realism, and statistical rigor in NCA5—but it’s shaped by a strong counter-narrative lens. Its scientific merit would be strengthened by more diverse sourcing, clearer separation of analysis and editorialism, and a broader epistemic perspective.

From: Judith Curry <curry.judith@gmail.com>

Sent: Sunday, July 13, 2025 3:12 PM

To: Ross McKittrick <ross.mckittrick@gmail.com>

Cc: Steven Koonin <steven.koonin@gmail.com>; John Christy <climateman60@gmail.com>; Roy W. Spencer <roywspencer@hotmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>; Josh Loucks <loucksj14@gmail.com>; Seth Cohen <seth.cohen@hq.doe.gov>

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see attached for a shorter, desnarked version of NCA5 for you to consider. I didn't do track changes, its clean text

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<image001.jpg>

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There's a lot of that about, even in Canada

<https://nationalpost.com/news/politics/canadians-drastically-downgrade-climate-as-a-priority-poll-finds-as-economic-concerns-escalate>

On Fri, Jul 11, 2025 at 2:47 PM Steven Koonin <steven.koonin@gmail.com> wrote:

Interesting data on one component of our audience:

<https://x.com/townhallcom/status/1943307220705223127>

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Attachments: NCA5.ReviewJuly10.docx; SI.Precipt_trends_reproducing.docx

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1. Whether to drop Section 1.4

- my thinking is I like the idea of the section because it justifies why we would presume to critique a report that has already gone through 11 government agencies and a National Academies review. At the same time I think it could be shortened and made more effective with a different version of the Figure from CWG25. John if you can you send me the spreadsheet you used I'll propose a rewrite.

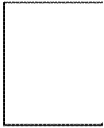
2. Do we include a case study of the Texas floods?

- What I like about that section is that it is a vivid example of how a document that could have provided useful info for disaster planners not only failed to do so, but it would have misdirected resources if they were to have relied on it. But it's easy to have 20/20 hindsight. Presumably somewhere in the US at this moment there are several potential weather-related hazards poised to cause death and destruction later this year, and the local authorities are not ready for them. We need to explain what it would look like for an NCA to be a useful resource in that context. What say ye all?

3. Tidying

- I find the LLM critiques to be somewhat helpful in anticipating possible lines of attack, but they are overly algorithmic and often end up saying "they make a valid point but that's not the consensus so it's probably wrong." And it seems to have hallucinated about things we didn't even say. Still, it points to the need to guard against snark.

--



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Critique of the Fifth National Climate Assessment

EXECUTIVE SUMMARY	3
1 INTRODUCTION	4
1.1 ABOUT THIS REPORT	4
1.2 ABOUT THE NATIONAL CLIMATE ASSESSMENTS	4
1.3 STANDARDS FOR ASSESSING NCA PRODUCTS	5
1.4 WHEN PEER REVIEW FAILED	6
2 NCA5 OVERVIEW CHAPTER: HYPERBOLIC ADVOCACY LANGUAGE AND UNSCIENTIFIC TONE.....	9
3 OVERCONFIDENCE WHEN STATING CONCLUSIONS	11
3.1 INFLATED CERTAINTY LEVELS.....	11
3.2 OVERSTATING FINDINGS IN UNDERLYING SOURCES	12
3.3 TECHNICAL EXAMPLE: EMERGENT CONSTRAINTS	13
4 ARBITRARY AND AMBIGUOUS TREND ANALYSIS.....	15
4.1 AVERAGE AND EXTREME PRECIPITATION.....	15
4.2 HEATWAVES.....	16
5 INADEQUATE TRACEABLE ACCOUNTS.....	19
6 OVEREMPHASIS ON EXTREME SCENARIOS	21
7 CONFLATION OF NATURAL AND ANTHROPOGENIC CLIMATE CHANGES	23
8 SUMMARY EVALUATION OF NCA5 AND RECOMMENDATIONS FOR NCA6.....	24
8.1 COMPLIANCE WITH USGCRP'S STATUTORY OBLIGATION	24
8.2 ADHERENCE TO THE TENETS OF GOLD STANDARD SCIENCE.....	25
8.3 SUITABILITY FOR INFORMING FEDERAL CLIMATE AND ENERGY POLICY	26
8.4 RECOMMENDATIONS FOR NCA6.....	26
9 REFERENCES	28
APPENDICES.....	30
APPENDIX 1: CHARGE TO THE REVIEW	30
ABOUT THE AUTHORS.....	31

EXECUTIVE SUMMARY

This report critically evaluates the Fifth National Climate Assessment (NCA5), finding it an inadequate basis for climate and energy policies. A detailed review of the foundational chapters on climate science raises several key concerns:

Scientific Integrity

- An advocacy tone, particularly in the Overview chapter, that is inconsistent with scientific objectivity
- Endemic overconfidence when stating conclusions, including inflated certainty levels and overstatement of findings from underlying sources

Flawed methodology

- Use of short time periods for trend analyses; more generally lack of a consistent rule for choosing time scales
- Overemphasis on extreme scenarios for future emissions and sea level rise
- Inadequate traceable accounts to support key conclusions

Deficient Review Process

- A review by the National Academy of Sciences, Engineering, and Medicine (NASEM) failed to challenge some fundamental flaws in NCA5
- The NCA5 authors failed to adopt some improvements recommended by NASEM

The report shows NCA5 to be a biased and incomplete picture of climate science that skews toward excessive climate risk. Consequently, NCA5 should not be used as basis for climate and energy policies.

1 INTRODUCTION

1.1 About this Report

This report responds to a request from the Office of Science and Technology Policy (OSTP) Director Michael Kratsios (reproduced in Appendix 1) that we assess the suitability of the Fifth National Climate Assessment (NCA5 2023) for informing climate and energy policies.

To conduct this assessment, we reviewed NCA5 itself, the National Academies of Science, Engineering and Medicine (NASEM) review of the Third Order NCA5 Draft, and the USGCRP responses to that review. We have drawn upon our long experience working on advisory reports, including for the NASEM, the Intergovernmental Panel on Climate Change (IPCC) and other organizations, as writers, reviewers and study leaders.

We find that NCA5 should not be relied on for policy making as it is an incomplete and misleading picture of our understanding of the changing climate and the risks it poses to the nation. NCA5 was selective and incomplete in its survey of climate science. Further, we have reviewed recent scientific developments in a separate report to Energy Secretary Wright (Climate Working Group 2025, herein denoted “CWG25”). The overall effect of the biases and omissions of NCA5 is an excessively dire picture of climate risk.

To support our finding, the following sections of this chapter provide some background on the National Climate Assessments and the standards by which we have assessed NCA5. Chapters 2 through 7 detail important ways in which NCA5 fails to meet those standards. Finally, Chapter 8 summarizes our evaluation of NCA5 and makes recommendations for NCA6.

1.2 About the National Climate Assessments

The U.S. Global Change Research Program (USGCRP) was established by Presidential Initiative in 1989 and mandated by Congress in the Global Change Research Act (GCRA) of 1990 to develop and coordinate “a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change.”

The National Climate Assessment (NCA) Reports evolved from the GCRA requirement to:

Prepare and submit to the President and the Congress an assessment which (1) integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings; (2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and (3) analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

The five NCA Reports to date have interpreted this mandate in different ways:

- NCA1 (2000) was a multidisciplinary effort to study and portray in regional detail the potential effects of human-induced global warming on the United States.

- NCA2 (2009) was a relatively short report that not only focused on the potential consequences of climate change but also sought to identify potential adaptation measures and identify the highest priorities for future research.
- NCA3 (2014) was an expanded effort that continued along the lines of NCA2, and was distinguished by a comprehensive review process, including a review by the National Academy of Sciences. NCA3 introduced a traceability analysis for each key finding, including a description of uncertainties.
- NCA4 (2017/2018) was a further expanded effort that was published in two volumes: I Climate Science Special Report (CSSR), and II Impacts, Risk, and Adaptation in the United States. This was the first NCA report to devote significant effort to assessing climate science.
- NCA5 (2023) returned to a single volume format, reducing discussion of climate science to a cursory two chapters, with continuing focus on regional and sectoral impacts of climate change. NCA5 expanded its remit to topics that are arguably outside the purview of the USGCRP, focusing on “Climate Action” and policy recommendations with a social justice emphasis.

These successive interpretations of the NCA are poorly aligned with the GCRA’s statutory requirements. Only NCA4 gives serious consideration to climate science, which receives the great majority of USGCRP funding, and even then NCA4 misrepresents some important points. Natural climate variability is essentially dismissed as unimportant in NCA4 and barely mentioned in NCA5 in most contexts, despite the mandate to include both human-caused and natural climate change. Most significantly, NCA5 has redirected the focus away from climate science and even the hazard elements of impacts, towards evaluation of societal vulnerabilities and advocacy for particular policy options, especially deployment of wind and solar generation. The cover image for the NCA5 Report is the installation of a solar panel.

1.3 Standards for Assessing NCA Products

Beyond the statutory requirements stated above, another pertinent standard is President Trump’s executive order of May 23, 2025, Restoring Gold Standard Science. It enumerates some of the characteristics of good science, namely that it should be:

- i. reproducible;
- ii. transparent;
- iii. communicative of error and uncertainty;
- iv. collaborative and interdisciplinary;
- v. skeptical of its findings and assumptions;
- vi. structured for falsifiability of hypotheses;
- vii. subject to unbiased peer review;
- viii. accepting of negative results as positive outcomes; and
- ix. without conflicts of interest.

Although these should be self-evident to those trained in science, it is surprising that some scientists have found them controversial (Dellawalla et al. 2025).

====debated text:

When science is assessed for the purpose of climate policymaking there are further requirements to bear in mind. Good climate and energy policies should balance the risks and benefits of a changing

climate against the world's growing demand for reliable and affordable energy. To strike that balance, policymakers must understand at least two complex and nuanced topics: the certainties and uncertainties of climate science and the technoeconomic realities of energy systems. Experts in those subjects have a responsibility to communicate their understanding to non-experts clearly, completely, and without bias.

Much expertise in energy systems resides in the private sector, where it is essential to providing the reliable and affordable energy services that are the lifeblood of society. Understanding is therefore continually refined and tested by operational demands and the discipline of the marketplace. In contrast, climate science expertise is found largely in the non-profit realm of universities and government laboratories and so has a more academic character, with greater uncertainties and hence need for expert judgement.

=====

For those reasons assessments of climate science that will be influential for policy making must include statements about the strength of knowledge. The IPCC's approach to assessing strength of knowledge is based on judgment of the available evidence and agreement among experts. But there are more sophisticated knowledge characterizations for risk management. Here are the elements according to Aven (2017):

- The degree to which the assumptions made are reasonable/realistic based on background knowledge
- The degree to which data/information exists and are reliable and relevant
- The degree to which there is disagreement among experts (including those from different environments or academic fields)
- The degree to which the phenomena involved are understood and accurate models exist
- The degree to which the knowledge has been thoroughly examined with respect to unknown knowns (issues that are known to matter but are ignored, such as, in this context, natural variability).

1.4 When Peer Review Failed

Peer review of reports like IPCC and NCA products is not a silver bullet that guarantees quality. The peer review process for these reports differs in some important respects from traditional peer review in academic journals. First, during the open review phases of early NCA drafts reviewers are volunteers who self-select what parts of the report to read, whereas the editors of academic journals editors recruit reviewers with relevant expertise and assign them to specific papers. As a result, there is no guarantee at that stage that any particular section of an NCA report was reviewed by anyone, let alone by someone with relevant expertise and a perspective that differs from the authors. In fact, many potential reviewers have given up over the years because their input has been systematically ignored. The introduction of a NASEM review stage is at best a partial remedy for this. However, NCA authors have near complete authority whether to accept or reject reviewer comments. By contrast, the Editor of an academic journal mandates the author to respond, and the reviewer and Editor assess its adequacy. Finally, the work of an NCA chapter author team is guaranteed to be published, whereas academic journals routinely reject papers that do not pass review.

These points are important to bear in mind because some readers might dismiss any criticism of NCA products out of hand on the grounds that they were "peer reviewed". But the test of a report is whether its contents are a valid representation of the available evidence. Here we give an example in

which NCA4 gave prominence to a figure that completely misrepresented the underlying data and which evaded peer review to do so. Further details can be found in Koonin (2024).

NCA4's Part I says (prominently and with *Very High Confidence*) on Page 19 of the Executive Summary:

There have been marked changes in temperature extremes across the contiguous United States. The number of high temperature records set in the past two decades far exceeds the number of low temperature records.

and offers this figure in support:

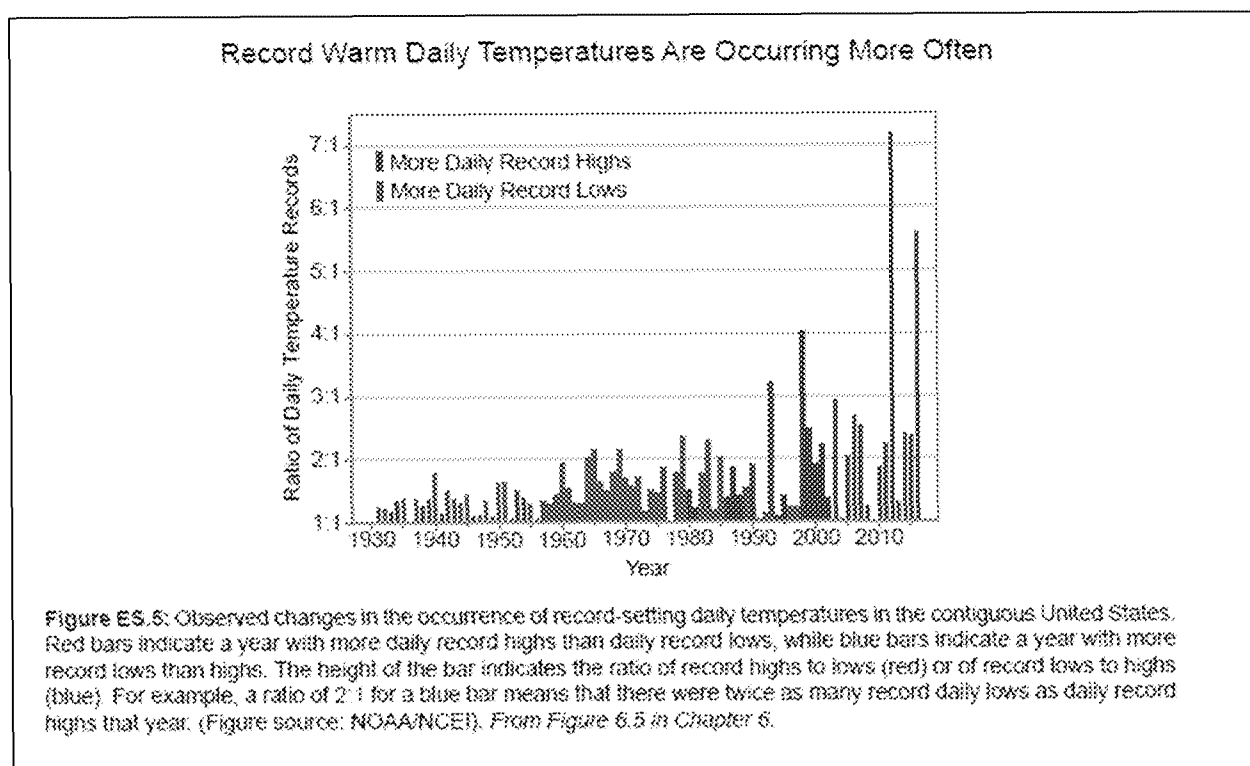


FIGURE 1: Reproduction of Figure ES.5 from NCA4

The figure appears to validate the claim that record warm daily temperatures are occurring more often. But the underlying data do not. Rather, they show that extreme heat in the U.S. peaked in the 1920s and 1930s and declined thereafter, as supported by Figure 6.4 deep within the CSSR itself (reproduced in Section 4.2 of this report).

Figure ES.5 does not even show what its title implies, as it displays not simple counts of cold and warm extreme events, but rather ratios of the two counts. As defined in the analysis, both types of extremes declined over the sample interval, but cold events declined more than warm events, so the ratio of warm extremes to cold extremes increased. By graphing the ratio instead of counts, NCA4 created a visual impression opposite to what is in the data.

Figure 6.3.3 of CWG25 (reproduced below) shows the results of a proper analysis and presentation of the data – defining each record as the singular extreme in the sample interval, displaying numbers

of warm and cold records separately, and beginning the analysis in 1899 rather than 1930. It makes evident the exceptional heat of the 1920s and especially the 1930s, peaking in 1936. (The increased heat of the past five years is too brief to be deemed climatically significant and, in any event, occurred after the CSSR was published in 2017.) The frequency of cold records has declined, especially over the last quarter of the period in which only 13 percent of the extreme cold events were measured. In contrast, 25 percent of the heat records were achieved in the last quarter, which is consistent with statistical expectations. As a result, the ratio of hot to cold extremes shown in Figure ES.5 of the CSSR explodes in recent decades. The overall reduction in numbers of both cold and hot extremes over the past century indicates a climate *less* prone to extremes, in sharp contrast to the message of NCA4 Figure ES.5.

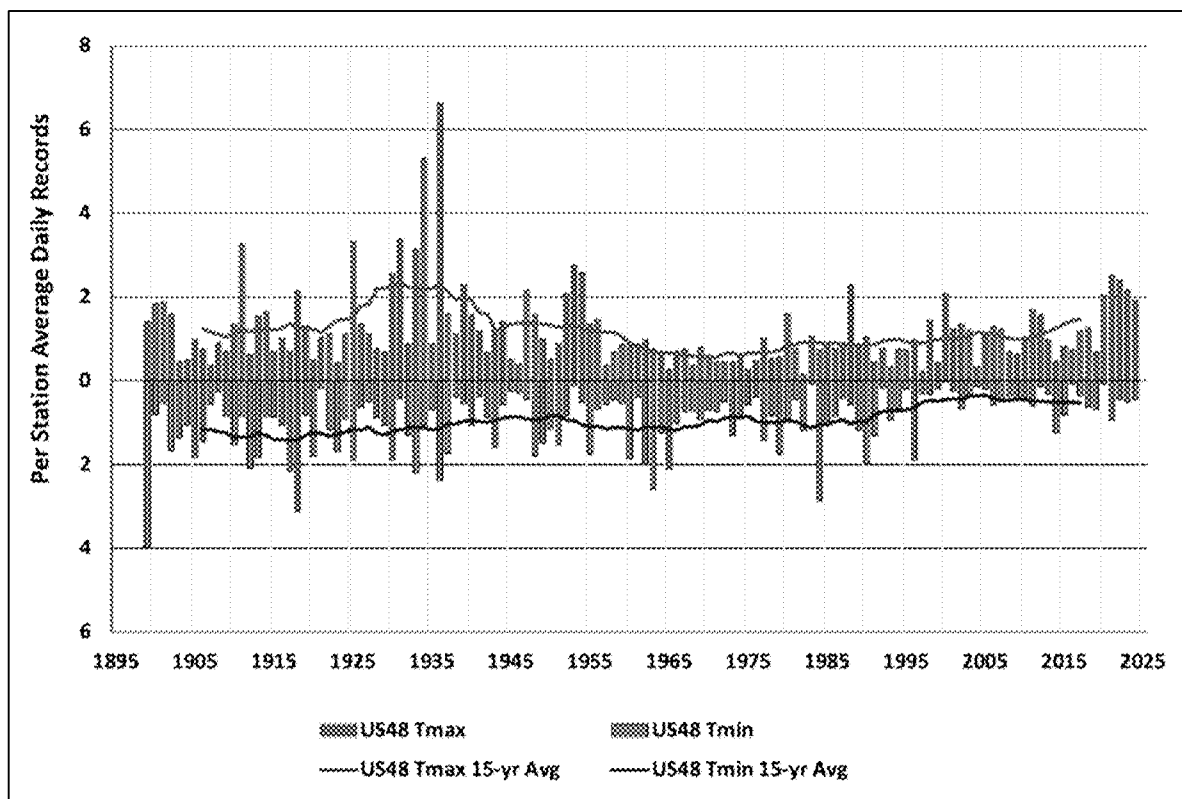


FIGURE 2: Number of daily record High (red) and Low (blue) temperatures for warm and cold seasons in the CONUS. The lines represent the 15-year running, centered average. Source: 1,211 USHCN stations supplemented as needed to achieve a minimum of 92 percent of observations in the 126-year period since Dec 1898. US48: contiguous U.S. states. Tmax: maximum temperature. Tmin: minimum temperature. Source: CWG25 Figure 6.3.3.

How did the flawed figure ES.5 pass the NCA4 NASEM Review? The NASEM Review panel criticized the discussion of temperature extremes in a late draft of the CSSR. Key Finding 2 of Chapter 6 in that draft stated:

Accompanying the rise is [sic] average temperatures, there have been – as is to be expected – increases in extreme temperature events in most parts of the United States. Since the early 1900s, the temperature of extremely cold days has increased throughout the contiguous

United States, and the temperature of extremely warm days has increased across much of the West. In recent decades, intense cold waves have become less common while intense heat waves have become more common. (*Extremely likely, Very high confidence*)

In reference to this NASEM said:

Further, it is difficult to understand how a statement that includes increases in extreme warmth can be associated with a high confidence or extremely likely statement, given that most of the graphics in this chapter show a decrease in extreme warmth in the historical record.

The Federal official in charge of the CSSR (Michael Kuperberg, Executive Director of the USGCRP) responded to the Academies' review by noting that

Almost every recommendation from the NAS was incorporated [in the final version]... and a new figure was added on changes in record high and low temperatures

The "new figure" referred to is the misleading Figure ES.5, which did not appear in the draft reviewed by the Academies' panel. It seems unlikely that the Academies panel ever saw that figure because they surely would have commented if they had and it wouldn't have survived to publication. And the figure's problems were evidently not flagged (or were ignored) in the subsequent internal government reviews.

With this background from NCA4, we now present our critique of NCA5.

2 NCA5 OVERVIEW CHAPTER: HYPERBOLIC ADVOCACY LANGUAGE AND UNSCIENTIFIC TONE

NCA5 Chapter 1, "Overview", holds a prominent place in the Report since it summarizes the entire report and is the only section that many will read. Although some material in the later chapters of NCA5 is not without merit, Chapter 1 is marred by an activist tone and language that aggressively promotes mitigation policies. As such, this chapter adds an imprimatur of scientific authority to naïve and simplistic declarations of opinion about public policy. Many examples can be cited; here we note a few that are particularly egregious.

Chapter 1 opens as follows:

The more the planet warms, the greater the impacts. Without rapid and deep reductions in global greenhouse gas emissions from human activities, the risks of accelerating sea level rise, intensifying extreme weather, and other harmful climate impacts will continue to grow. Each additional increment of warming is expected to lead to more damage and greater economic losses compared to previous increments of warming, while the risk of catastrophic or unforeseen consequences also increases.

This statement presupposes that all warming is anthropogenic, that all warming is bad and causes economic damage, and that warming intensifies extreme weather. Such sweeping generalizations go well beyond what science has or can establish. The statement also refers to growing risks without saying whether they were large to begin with – a small risk that grows may still be a small risk, and a large risk may be only incrementally worsened.

On the next page the Overview states:

Each additional increment of warming leads to greater risks [here it lists 7 key components of society including food security and the economy]... Without deeper cuts in global net emissions, climate risks to the US will continue to grow... Action to limit future warming and reduce risks can have near-term benefits and opportunities: low-carbon energy jobs, Improved air quality, Health benefits, Economic benefits..."

The authors write as if climate policy does not involve trade-offs and all measures to reduce future warming will be effective and beneficial. Neither the vast body of scholarship on climate science and economics, nor historical experience, support such simplistic claims (CWG25 ch.XX). Not every additional increment of warming leads to economic harms; in fact, NCA5 Chapter 19 acknowledges that there will also be benefits. Nor is climate policy guaranteed to benefit the economy; it could impose net costs. Such misleading statements are a disservice to policymakers.

Pages 8 and 9 of the Overview promote renewable energy options by noting, correctly, that the levelized costs of wind/solar generation have fallen sharply since 2010, and so offers this rationale for pursuing deep emission reductions:

Recent growth in the capacities of wind, solar, and battery storage technologies is supported by rapidly falling costs of zero- and low-carbon energy technologies, which can support even deeper emissions reductions. For example, wind and solar energy costs dropped 70% and 90%, respectively, over the last decade, while 80% of new generation capacity in 2020 came from renewable sources.

Yet it has long been known that intermittent renewables generation must be supplemented by dispatchable generation to meet grid reliability standards, and that doing so (e.g., through natural gas, fission, or storage) significantly increases the cost of electricity. Further, there are yet unmet synchronization challenges in electrical grids with heavy penetration of wind and solar generation. Here again it is advisory malpractice not to acknowledge these facts. But more importantly, we see no reason for NCA5 to be discussing renewable energy technologies and economics in the context of its mandate.

Page 14 of the Overview presents future emission scenarios with the following description: "Climate modeling experts develop global climate projections for a range of plausible futures." The word "plausible" is applied to all the scenarios. The accompanying figure includes both SSP3-7.0 and SSP5-8.5, the latter reaching the same radiative forcing as RCP8.5. The figure does not compare observed emissions with previous projections, nor does it caution readers that SSP3-7.0 and SSP5-8.5 are extreme scenarios that, like RCP8.5, have been heavily criticized in the scientific literature as being implausible (CWG25 3.2.1). By describing the entire envelope of emission projections as "plausible" the report opens the door to later presenting impacts associated with implausible worst case emission scenarios as part of a baseline "business-as-usual" future.

Page 17 of the Overview introduces the discussion of risks from extreme weather events by saying “Harmful impacts from more frequent and severe extremes are increasing across the country.” This creates the impression that extreme weather events are worsening and that disaster losses are driven by trends in extreme weather. While the section goes on to acknowledge that some of the increase is due to increases in the value of assets at risk, it then invokes the NOAA Billion Dollar Dataset as evidence of extreme weather getting worse. Scientists have shown that this is an invalid metric (CWG 10.2) since it measures the growth of the economy not the frequency of extreme weather, and indeed NOAA has recently withdrawn the data product (Pielke Jr. 2024, 2025). Even though the dataset was still distributed by NOAA at the time of the NCA5, the report authors failed to assess it skeptically and see that it was unfit for the purpose of measuring climate trends.

Page 23 of the Overview states, in large font:

Climate changes are making it harder to maintain safe homes and healthy families; reliable public services; a sustainable economy; thriving ecosystems, cultures, and traditions; and strong communities.

It is pointless to try to evaluate this statement on scholarly grounds; it is self-evidently hyperbolic. This kind of language doesn’t belong in a scientific assessment report. Its prominent inclusion points not only to the willingness of NCA5 authors to promote alarm, but also the ineffectiveness of the review process in eliminating such statements.

3 OVERCONFIDENCE WHEN STATING CONCLUSIONS

3.1 Inflated certainty levels

Overconfidence in stating conclusions has been an endemic problem in NCA Reports. The authors frequently make sweeping generalizations without appropriate caveats or acknowledging uncertainties. The overconfidence begins with inflated language to describe certainty levels.

NCA5 uses specific terms to convey information about scientific confidence associated with important finds, observations and projections. The Front Matter of NCA5 states that

confidence in a finding is based on the type, amount, quality, strength, and consistency of evidence; the skill, range, and consistency of methods to detect, evaluate, attribute, and interpret climate trends; and the degree of agreement across scientific information sources.

and Table 1 from the Front Matter provides calibrated language for confidence assessment:

Very high:	Strong evidence (established theory, multiple sources, well documented and accepted methods, etc.). High consensus
High:	Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.). Medium consensus
Medium:	Suggestive evidence (a few sources, limited consistency, methods emerging, etc.) Competing schools of thought.
Low:	Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.). Disagreement or lack of opinions among experts.

This terminology is obviously inflated: *high confidence* with just moderate evidence and medium consensus; *medium confidence* with only suggestive evidence and competing schools of thought. This inflation in terminology leads to overconfidence in conclusions.

Even with this inflated terminology, NCA5 further inflates the confidence level of many of its conclusions to well beyond what the IPCC has concluded with more thorough justification, and by incorrectly applying its own standards. An example is the conclusion about anthropogenic influence on climate change, arguably one of the most important scientific statements of the report.

Key Message 3.1 Traceable Account states:

There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have unequivocally caused *all* global warming observed over the industrial era.

while the corresponding statements from IPCC AR5 and AR6 are

AR5: It is *extremely likely* that *more than half* of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together. (IPCC, 2013)

AR6: The *likely* range of total human-caused global surface temperature increase from 1850–1900 to 2010–2019 is 0.8°C to 1.3°C, with a best estimate of 1.07°C. It is *likely* that well-mixed GHGs contributed a warming of 1.0°C to 2.0°C, other human drivers (principally aerosols) contributed a cooling of 0.0°C to 0.8°C, natural drivers changed global surface temperature by –0.1°C to +0.1°C, and internal variability changed it by –0.2°C to +0.2°C. It is *very likely* that well-mixed GHGs were the main driver of tropospheric warming since 1979.

The IPCC AR5 and AR6 statements provide likelihood assessments but not a confidence level. While NCA5 claims with *very high confidence* that fossil fuels have unequivocally caused *all* global warming, AR5 refers to “*more than half* of the observed warming” and AR6 provides a more nuanced statement that relates to a *likely* range of warming contributed to by human drivers.

3.2 Overstating findings in underlying sources

Although we did not do a detailed audit of NCA5’s use of source material, spot checks suggest a pattern of overstatement.

Chapter 2 page 11 reports on an increase in precipitation in some areas and attributes it to “climate change”:

Many eastern regions of the country are getting wetter (Figure 2.4). Average annual precipitation from 2002-2021 was 5%-15% higher relative to the 1901-1960 average in the central and eastern US, a trend attributable to climate change.

The claims were attributed to Knutson and Zeng (2018). But Knutson and Zeng did not say these things nor analyze this particular period. They said (emphasis added):

Observed annual precipitation trends over the recent 30-yr period 1981–2010 (Fig. 5) have generally stronger magnitudes (in mm yr⁻¹ decade⁻¹) than observed trends for 1901–2010 or 1951–2010. This is as expected since trends over a shorter period have stronger potential for occurrence of pronounced temporary trends due to internal variability alone. **Only 9% of the analyzed area has detectable and attributable anthropogenic influence (categories -3, -2, +2, +3), which represents less than one-third of the fractional areal coverage of such trends for 1901–2010 (29%).** ... Eight percent of the analyzed area has attributable anthropogenic *increases* (categories +2, +3), including parts of eastern Europe, northern Asia, northern Australia/Maritime Continent, and tropical Africa.

Thus for 1981–2010 they cautioned that observed changes are consistent with natural variability, and they did not claim attributable trends were observed over the United States.

As another example of overstating findings, NCA5's Chapter 2 page 18 states

There is robust evidence that human-caused warming has contributed to increases in the frequency and severity of the heaviest precipitation events across nearly 70% of the US.

This is apparently attributed to two papers Diffenbaugh *et al.* (2018) and Kirchmeier-Young and Zhang (2020). Diffenbaugh *et al.* presented ratios of observed occurrences of extreme events to simulated occurrence rates in CMIP6 models run with only natural forcings. They report that for 79% of the U.S., extreme rainfall events are currently more frequent than in simulations, and the ratio of occurrences will rise under future warming simulations. This is not “robust” evidence of anthropogenic influence since it requires readers to assume that climate models accurately simulate regional precipitation patterns, something that even IPCC AR6 admits is uncertain (AR6 WGI SPM Box SPM 1.2, SPM Section C.1.3).

Kirchmeier-Young and Zhang looked at extreme 1- and 5-day events in North America and, using three global climate models, found

A signal of combined anthropogenic and natural external forcing can be detected in the intensification of extreme precipitation at the continental scale over North America. In some cases, this intensification can be attributed to human influence specifically.

However, they noted large differences among the three models in their simulated precipitation changes, and two of the three models failed to yield attribution for 5-day events for the North America mean. In other words, the models disagreed on whether the observed changes were anthropogenic. Both of the cited references utilized the implausible RCP8.5 scenario and began their “historical” observational records only in 1961. Here again this is not “robust” evidence, it is merely suggestive, particularly since other studies have found natural variability predominant.

3.3 Technical example: Emergent constraints

Some of the overconfidence expressed by NCA5 arises by omitting discussion of counterevidence in the peer reviewed literature. An example is the topic of “emergent constraints”. Chapter 3 page 17 invokes this concept to support its claim that key uncertainties in climate model projections have been reduced:

An approach to reduce uncertainty in climate change projections has matured over the past decade. It is known as "emergent constraints." The term refers to strong statistical relationships between highly uncertain future climate parameters and observable trends or variations in the current climate, along with a physical explanation of this relationship.

Emergent constraints appeared in the climate modeling literature as an attempt to tie climate model behavior to climate observations in hopes of generating insight into real-world equilibrium climate sensitivity to a doubling of carbon dioxide (ECS). Climate models exhibit a wide range of ECS values. The idea of emergent constraints is to examine whether the models with shared sensitivity values also share a common representation of some climate process (usually related to clouds) that might influence ECS. Suppose, for instance, that in low-ECS models the total cloud fraction in the tropics is strongly correlated with that in the southern midlatitudes, but in high-ECS models the correlation is weak. Then researchers could examine whether the observed correlation is strong or weak and draw a conclusion about which type of model, and therefore which ECS value, is more likely.

A problem in the emergent constraint literature is that there has been a proliferation of proposed correlations with little physical motivation. NCA5 alludes to this in the Traceable Accounts section (p. 3-40) but not in the main Chapter text. As shown by Schlund *et al.* (2020) many emergent constraints patterned on CMIP5 models (Coupled Model Intercomparison Project No. 5, used for the IPCC 5th Assessment Report) failed to work on CMIP6 models (used for the IPCC 6th Assessment Report). In other words, the observed correlations in CMIP5 models between ECS and cloud processes failed to show up in CMIP6 models, indicating that they were likely spurious rather than clues to physical processes governing the climate system. As a result, emergent constraints estimated on CMIP5 models *increased* the uncertainty of ECS, rather than decreasing it as intended and as claimed by NCA5.

Schlund *et al.* summarized the problem as follows [**boldface** added for emphasis]

In this study, we systematically analyze 11 published emergent constraints on ECS that have mostly been derived from models participating in the Coupled Model Intercomparison Project Phase 5 (CMIP5) project... The focus of the study is on testing if these emergent constraints hold for [Earth System Models] participating in the new Phase 6 (CMIP6). Since none of the emergent constraints considered here have been derived using the CMIP6 ensemble, CMIP6 can be used for cross-checking of the emergent constraints on a new model ensemble. **The application of the emergent constraints to CMIP6 data shows a decrease in skill and statistical significance of the emergent relationship for nearly all constraints, with this decrease being large in many cases.** Consequently, the size of the constrained ECS ranges (66% confidence intervals) widens by 51% on average in CMIP6 compared to CMIP5.

Yet NCA5 described the use of emergent constraint analysis as an advance that reduced uncertainty of ECS and climate model projections (p. 3-38):

Emergent constraints have been widely applied to reduce the simulated spread in the climate feedbacks that shape climate sensitivity.

4 ARBITRARY AND AMBIGUOUS TREND ANALYSIS

In CWG25 Chapter 6 we discussed the need for care in the choice of time scale when making claims about trends in extreme weather. We provided examples from analysis of river flooding, heatwaves, and extreme precipitation to show how assertions about apparent trends based on short data sets fall apart when looking at longer versions of the same data sets. NCA5 uses varying time scales for trend discussions, especially in Chapter 2 (which is focused on trends), without explaining why shorter or longer intervals were chosen. For example, page 2-4 defines temperature trends with respect to the interval since the late 1800s whereas page 3-29 presents temperature trends over 1972-2021. Page 2-11 compares rainfall over the 2002-21 versus 1901-1960 intervals while page 2-18 uses the interval since the late 1950s to compute trends.

A further problem is that NCA5 uses term “trend” repeatedly without indicating if it is statistically significant (*i.e.* distinguishable from random variability); the ambiguity creates the impression all the observed changes were significant, but readers are left to speculate. All climate variables will, in principle, drift up or down over any particular time interval. Identifying the change as a trend requires showing that it is statistically significant using a variance estimator suitable for the type of data being analysed. Of particular importance is choosing a method robust to serial correlation which is frequently present in climate data. Throughout Chapters 1 to 3 references are made to “trends” without explaining how they were computed. The exception was on page 1-19 which refers to urban temperature trends being calculated using the Theil-Sen estimator, although that method does not seem to have been used elsewhere. The one case where reference is made to statistical significance was on Page 2-9 referring to a trend in Atmospheric Optical Depth but no explanation is given of how significance was determined. Page 2-19 refers to regional trends in droughts being “robust” but again fails to explain how the term was defined.

In this chapter when we refer to calculation of trends in precipitation, we use ordinary least squares to compute the linear trend over the entire sample length and we use the Vogelsang and Franses (2007) variance estimator which is robust to general forms of serial correlation.

4.1 Average and Extreme Precipitation

McKittrick and Christy (2019) showed that trends in U.S. average and extreme precipitation that appeared to be positive and significant over the NCA4 interval (1901 – 2016) lost significance and/or changed sign on longer samples (extending back as far as the 1840s, depending on location) or on a shorter interval coinciding with the final 40 years of the data then available (1978 – 2017). In CWG25 Section 6.4 we presented analyses of updated data for the same locations (and many others), in all cases finding both considerable regional heterogeneity and that trends detectable on one time scale are often not detected on longer or shorter time scales. These findings argue against simple attribution of changes to anthropogenic influences.

NCA5 did not continue the NCA4 precedent of using the post-1901 interval as the time scale for its precipitation discussion. Instead it refers to changes “since the 1950s”; NCA5 Figure 2.8 suggests 1958 might be the intended start date. Under Key Message 2.2 “Extreme Events Are Becoming More Frequent and Severe” (p. 2-16) NCA5 states (p. 2-18):

Rainfall is becoming more extreme

Since the 1950s, there has been an upward trend in heavy precipitation across the contiguous US. This increase is driven largely by more frequent precipitation extremes, with relatively smaller changes in their intensity.

In addition to our concerns that inferences about trends are contingent on choice of time scale, if the intended meaning of this statement is that positive and significant trends are found in heavy precipitation events across CONUS we cannot reproduce it. We supplemented the data used in CWG25 (McKittrick and Christy 2025a) with 61 stations across the Midwest (Christy 2025). Many post-1950 trends are positive but statistically insignificant depending on the measure of extreme precipitation. It is possible to find locations that positive and significant trends, such as the Southeast post-1950, but those results are not robust to selecting longer or shorter time scales of analysis nor do they generalize across all regions (see details in McKittrick and Christy 2025b).

The following is a more accurate summary of what U.S. precipitation data show.

There are regionally heterogeneous changes in average and extreme precipitation. Positive trends in annual average rainfall and extreme events (defined either as the annual maximum or the number of exceedances of the 99th percentile value) are generally weak or non-existent when looking at samples exceeding 130 years in length. Significant trends can be found when beginning the sample in the 1950s although in most cases the trends weaken and become insignificant when looking at the post-1980 interval. This argues against attribution of changes in precipitation to anthropogenic warming.

4.2 Heatwaves

In contrast to NCA5, NCA4 examined heat extremes across the entire 20th century, pointing out that peak heat wave activity was reached in the 1930s and has decreased since then, and that recent increases are confined to areas west of the Rockies. NCA4 stated:

[The] warmest daily temperature of the year increased in some parts of the West over the past century, but there were decreases in almost all locations east of the Rocky Mountains. In fact, all eastern regions experienced a net decrease, most notably the Midwest (about 2.2°F [1.2°C]) and the Southeast (roughly 1.5°F [0.8°C]).

Since the mid-1960s, there has been only a very slight increase in the warmest daily temperature of the year (amidst large interannual variability). Heat waves (6-day periods with a maximum temperature above the 90th percentile for 1961–1990) increased in frequency until the mid-1930s, became considerably less common through the mid-1960s, and increased in frequency again thereafter. As with warm daily temperatures, heat wave magnitude reached a maximum in the 1930s.
(NCA4 pp. 190-191)

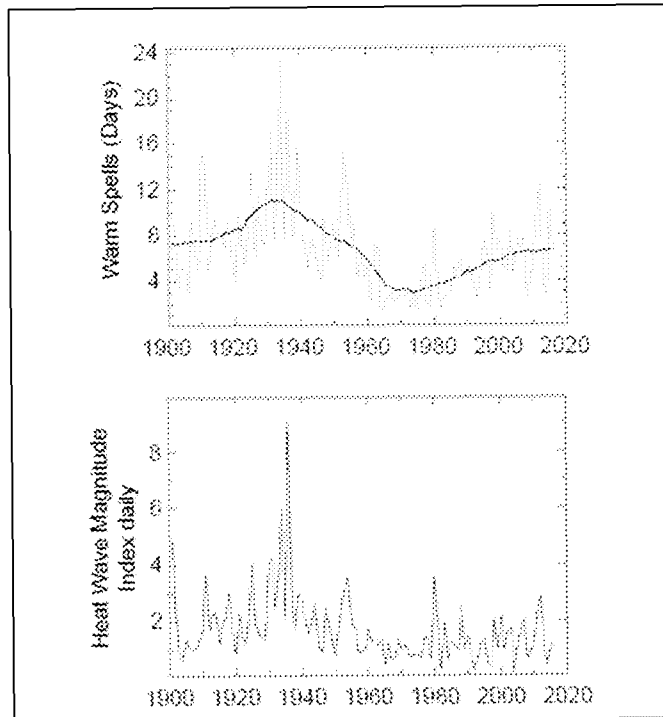


FIGURE 3. U.S. Heat waves since 1900. Reproduction of NCA4 Figure 6.4

Contrast this careful and factual language from NCA4 with NCA5 Key Message 2.2: “Extreme Events Are Becoming More Frequent and Severe.” This blanket statement is followed by NCA5 Figure 2.7 (reproduced as Figure 4 below) which shows the number of hot days, cold days and warm nights (respectively in panels a—c) over the period 2002-2021 compared to 1901-1960. [Presumably these are annual counts, although not stated in the caption.]

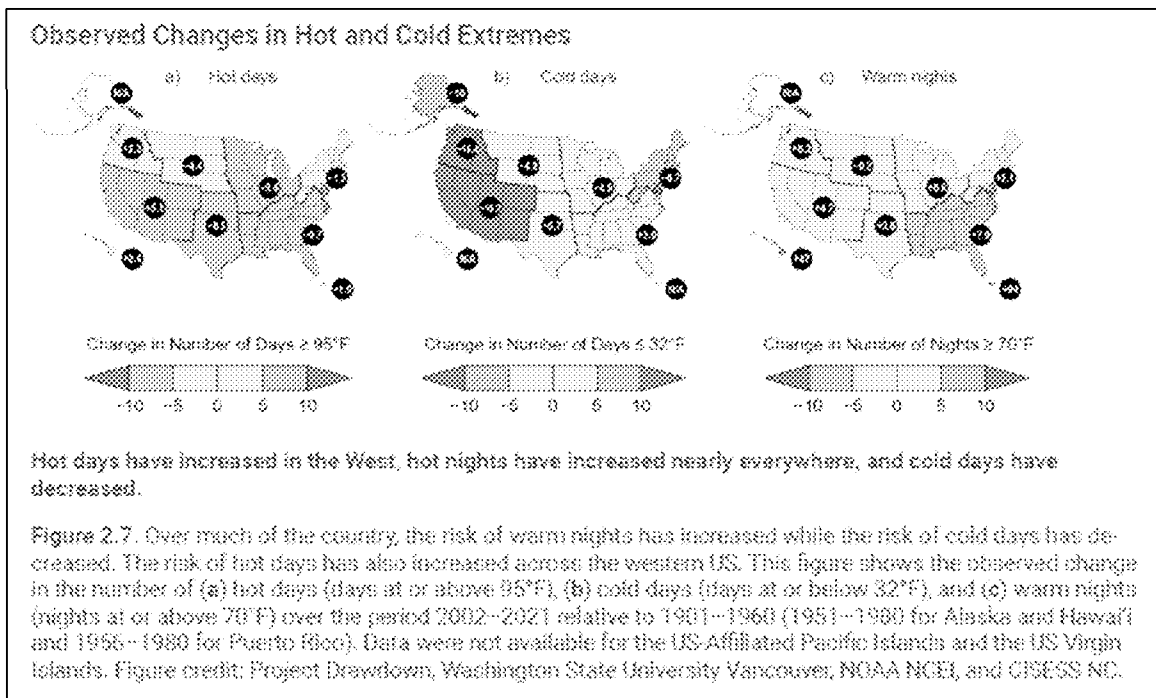


FIGURE 4: Reproduction of NCA5 Figure 2.7.

Close inspection shows that this figure actually contradicts the NCA5 Key Message with respect to heatwaves and instead reinforces the position of NCA4. Notwithstanding Key Message 2.2, the leftmost panel in NCA5 Figure 2.7 above shows that over most of CONUS the number of extreme heat days has *decreased* in recent decades compared to the prior century.

The accompanying discussion in NCA5 becomes convoluted as it appears to be aimed at supporting the Key Message despite the contrary evidence. NCA5 Chapter 2 elaborates on Key Message 2.2 by stating (page 16):

Observations show an increase in the severity, extent, and/or frequency of multiple types of extreme events. Heatwaves have become more common and severe in the West since the 1980s (*high confidence*).

But while it mentions the increase in hot days in the West, it fails to mention the decrease everywhere east of the Rockies. On the next page (page 17) it raises the comparison to the 1930s and then switches to discussing global counts:

By some measures, the most extreme heatwaves on record in the United States occurred during the Dust Bowl era of the 1930s. ... Globally such heatwaves are becoming more frequent, and in recent decades the western United States has been following those trends.

The reference to a global trend seems to be an attempt to tie heatwaves to anthropogenic climate change. But the obvious question, unaddressed by NCA5, is why one region follows the global pattern of increasing heatwaves while most of the country is trending in the opposite direction. These issues are addressed in Chapter 6 of CWG25, demonstrating that the range and magnitude of extreme temperatures (10s of degrees) are driven more by natural variability than by the small anthropogenic forcing. The analysis in CWG25 shows that for both (a) hot days ($\geq 95^{\circ}\text{F}$) and (b) number of days in heatwaves, the current decade is no hotter than a century ago in the U.S. Thus, the NCA5 claim that

“multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades,” is simply false when expanding the temporal and spatial domains to encompass all available data (Chapter 6 and Figure 6.3.6 of CWG25).

NCA5 then pointed to the dramatic Pacific Northwest heatwave of 2021. CWG2025 Section 8.6.1 discussed this event in detail, reviewing the multiple peer reviewed studies that explained the unusual meteorological context was unrelated to human-caused climate change, a point omitted from the NCA5 discussion.

NCA5 finally addresses the declining heatwave trend in CONUS east of the Rockies but attempts to reframe it by focusing on urban warm spells.

[The] number of very hot days has actually decreased across the central and eastern regions due to summer cooling trends in the region (Figure 2.7; Ch. 22). This does not, however, mean the central and eastern US are not affected by heat. The impacts of extreme high temperatures are more severe if such conditions persist for several days, and overall, multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades. Across 50 large US cities, the US Global Change Research Program heatwave indicator (<https://www.globalchange.gov/indicators/heat-waves>) shows that the average number of heatwaves has doubled since the 1980s, and the length of the heatwave season has increased from about 40 days to about 70 days.

We discussed this part of NCA5 in CWG25 Section 6.3. The figure referenced by NCA5 uses a short time period which begins in the 1960s, the coldest decade in the last 100 years, thus suppressing any comparison to the 1930s. Further, nighttime temperatures in urban areas have increased faster than daytime temperatures (which NCA5 acknowledges), but this is a signature of urban heat islands and not a good metric of climate change. CWG25 found that the occurrence of hot days ($\geq 95^{\circ}$ F) has recently increased in the West, but declined in the remainder of the country, and in the nationwide average, since 1899.

5 INADEQUATE TRACEABLE ACCOUNTS

NCA3 began the practice of including a section on Traceable Accounts at the end of each chapter. This is the description from NCA5:

Each chapter concludes with a section entitled Traceable Accounts, which provides information on the overall process used to develop the chapter as well as a separate Traceable Account section for each Key Message. These Traceable Accounts describe the supporting evidence behind each Key Message, the process and rationale authors used in reaching their conclusions, and the author team’s expert assessment of the confidence in and, where applicable, likelihood of these conclusions. As such, Traceable Accounts provide information about the state of the science, document sources of uncertainty, identify research gaps, and allow traceability to data and resources.

The Traceable Accounts for each Key Message includes the following sections:

- Description of Evidence Base

- Major Uncertainties and Research Gaps
- Description of Confidence and Likelihood

The Traceable Accounts could have addressed the statutory requirement that the NCA discuss scientific uncertainties. They could also help satisfy the Executive Order for Restoring Gold Standard Science by addressing reproducibility, transparency, communication of error and uncertainty, and skepticism of findings and assumptions. However, the Traceable Accounts in NCA5's Chapters 2 and 3 are uneven, often superficial and uninformative.

An example of a deficient Traceable Account is NCA5's Key Message 2.2: "Extreme Events are Becoming More Frequent and Severe". The "Description of the Evidence Base" offers two paragraphs, the first summarizing the findings and the second generically describing the types of data that can be used for storms. "Major Uncertainties and Research Gaps" focuses on the uneven distribution across U.S. populations due to differences in exposure and vulnerability. The only limitations in data referred to are the lack of a long-term record of lightning and the lack of homogenized daily and hourly temperature data apart from reanalysis products.

But the most astonishing deficiency is in the "Description of Confidence and Likelihood." One of the statements in Key Message 2.2 is:

Hurricanes have been intensifying more rapidly since the 1980s (*high confidence*) and causing heavier rainfall and higher storm surges (*high confidence*).

The Description of Confidence and Likelihood includes the following statement:

Basic physical understanding and climate models both provide robust explanations for the links between climate change and observed changes in these extremes: this is why the authors also have high confidence that storms are delivering more rainfall and high confidence that storm surges are becoming higher.

No reference to journal publications or a specific data set is made anywhere in the chapter regarding hurricane-induced precipitation or storm surge to support this *high confidence* conclusion.

The Traceable Accounts for the various Key Findings of Chapter 3 have some substantial inconsistencies. Consider

Key Message 3-1: Human activities have caused global warming.
Confidence and Likelihood: "There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have *unequivocally* caused all global warming observed over the industrial era. There is also *very high confidence* that changes in natural climate drivers have had globally small and regionally variable long-term effects over this period."

The Uncertainties section addresses only uncertainties in radiative forcing by greenhouse gases, ignoring the great uncertainty in model response (CWG25 Chapters 4&5) In contrast, the Traceability Analysis of Key Message 3-4 ("Humans Are Changing Earth System Processes") raises the problem that relatively little is known about the role of natural variability at the regional scale. From its Description of Evidence Base:

In the last decade, there has been increasing recognition of the role of regional-scale natural variability in the past and future evolution of climate, as well as the fact that regional natural variability signals can be competitive with forced anthropogenic signals.

And from its Major Uncertainties and Research Gaps:

For example, the true natural variability of the climate system on decadal to centennial timescales could be larger than what we estimate from GCMs, which would further increase the irreducible uncertainty stemming from natural variability.

These statements are among the most scientifically credible in the entire NCA5 and they directly undercut the confidence assigned to Key Message 3-1.

There is also a generic problem in tracing NCA5's Traceable Accounts. The Front Matter of NCA5 states:

Each figure and some tables are accompanied by a metadata survey, which can be accessed in the online version of the report by clicking on the eyeball icon above the figure or table (see the table below for explanations of additional icons used throughout the report). The metadata survey describes data sources, figure or table development methods, copyright information, and other important documentation.

Clicking on the 'eyeball' icon does not reveal the metadata information; instead a "Contact Us" email appears, addressed to the USGCRP. This is an inadequate way to archive the metadata information.

In summary, the Traceable Analyses examined here, with few exceptions, fail to meet the stated objectives of the NCA.

6 OVEREMPHASIS ON EXTREME SCENARIOS

To respond to the GCRA mandate to "project major trends for the subsequent 25 to 100 years," NCA5 relies on projections of future climate change based on estimates of future emissions (the so-called SSP scenarios) and/or specified levels of radiative forcing (the RCP scenarios). For the most part, NCA5 uses scenarios developed for the IPCC Assessment Reports.

In CWG Section 3.2.1 we presented a critical assessment of past and current IPCC scenario envelopes, showing that they have tended to overshoot observed emissions. IPCC AR6 published in 2021 stated that "The likelihood of high-emission scenarios like RCP8.5 and SSP5-8.5 is considered low in light of recent energy sector developments." and that same year UN Climate Negotiators (COP) stopped using scenarios above 4.5.

NCA5 makes the following observations about the scenarios they use:

NCA5 authors were advised to assess the full range of scenarios available. (Front Matter)

Scenarios of future emissions and land-use change are developed as plausible alternatives, but no relative likelihood is attached to them. Some recent studies, however, have argued that

the highest scenario, SSP5-8.5, is no longer plausible without a reversal of current trends in the adoption of renewables and energy efficiency. (Key Message 3.3 Traceable Analysis)

Despite acknowledging the issue, NCA5 otherwise ignored the problem. A keyword search of NCA5 of mentions of RCP/SSP scenarios finds over 50% referred to the extreme emissions scenarios RCP8.5/SSP5-8.5. Further, nine NCA5 figures (5.2, 6.9, 7.4, 11.3, 14.6, 22.13, 22.19, 27.9, 29.13) included *only* the 8.5 scenarios.

The problem of relying on extreme scenarios is particularly acute for NCA5's sea level rise projections. The sea level rise scenarios used in NCA5 do not relate directly to the SSP emissions scenarios, but rather to specified amounts of sea level rise by 2100. Table 4 of NCA5's "Guide to Using this Report" reproduced below shows that Low relates to 0.3 m (0.98 feet), Intermediate-Low relates to 0.5 m (1.64 feet), Intermediate relates to 1.0 m (3.28 feet), Intermediate-High relates to 1.5 m (4.92 feet), and High relates to 2.0 m (6.56 feet).

Table 4. Descriptive Terms for Common Sea Level Rise Scenarios Used in NCA5						
Future global mean sea level rise and sea level rise along United States coastline are shown for five scenarios in feet (and meters), relative to a 2000 baseline. The US values shown in the right half of the table are averaged across the US coastal regions, including the contiguous US, Alaska, Hawaii, and the US-Affiliated Pacific Islands, and the US Caribbean. The national values shown in the table differ substantially from regional values. For example, sea level rise is higher in the Gulf Coast and lower or even negative in some parts of Alaska. In the next 30 years (2020–2050), sea level along the contiguous US coasts is expected to rise 0.92 feet (0.28 m), the same amount of sea level rise observed over the last 100 years (1920–2020). See Chapter 9 for regional sea level information. Adapted from Sweet et al. 2022.”						
Sea Level Rise Scenario Descriptor	Global Mean Sea Level			United States		
Year	2050	2100	2150	2050	2100	2150
Low	0.49 (0.15)	0.98 (0.3)	1.31 (0.4)	0.59 (0.18)	0.98 (0.3)	1.64 (0.5)
Intermediate-Low	0.66 (0.20)	1.64 (0.5)	2.62 (0.8)	0.75 (0.23)	1.64 (0.5)	2.95 (0.9)
Intermediate	0.92 (0.28)	3.28 (1.0)	6.23 (1.9)	0.89 (0.27)	3.28 (1.0)	6.89 (2.1)
Intermediate-High	1.21 (0.37)	4.92 (1.5)	8.86 (2.7)	1.12 (0.34)	4.92 (1.5)	8.86 (2.7)
High	1.41 (0.43)	6.56 (2.0)	12.14 (3.7)	1.38 (0.42)	6.56 (2.0)	12.46 (3.8)

TABLE 1: Reproduction of Table 4 from the Front Matter of NCA5

Considering only projections representing processes quantified with at least medium confidence, IPCC AR6 assessed global mean sea level projections for all emissions scenarios (including implausible extreme emissions scenarios) for 2100 to fall between 0.2 and 1.6 m (5th—95th percentile range). Nevertheless, the range of sea level rise scenarios considered by NCA5 extends to 2.0 m. Further, NCA5 fails to include plausible lower scenarios, such as 0.2 m cited by the IPCC, which also corresponds to the average rate of sea level rise over the past century.

Chapter 9 of NCA5 offers the following predictions of sea level rise:

“Under a range of potential global warming levels, average sea level along US coastlines is *likely* to be between 12 and 20 inches above 2000 sea levels in 2050 (Figure 9.2).”

The projected sea level rise values span from the Intermediate scenario to values slightly greater than the High scenario. They can be put into context by considering the observed global sea level rise from 2000-2024, which is only approximately 3.4 inches (0.28 feet). **NCA5 is thus projecting a sea level rise during 2025 and 2050 that is 3.5 to 5.8 times the rate observed during 2000-2024, an exceedingly implausible outcome.** Chapter 9 further states:

“Looking toward the future, an 11 inch (28 cm) average rise along the contiguous US coastline is expected by 2050 (relative to 2020), with a *likely* range of 9-13 inches.”

...

“There is *high confidence* and it is *likely* that sea levels will rise about 11 inches (likely range of about 9–13 inches) between 2020 and 2050”

In summary, NCA5 presents future sea level rise scenarios that are not directly relatable to either SSP/RCP emissions scenarios or to plausible global warming levels. The NCA5 scenarios include two that are higher than the 95th percentile for the extreme emissions scenario RCP8.5 and include hypothesized ice sheet processes in which there is low confidence. Projections to 2050 require rates of sea level rise from 2025 to 2050 that are more than triple the rate observed during 2000-2024. Further, NCA5 ascribes *high confidence* to these sea level rise projections. CWG25 Section 7.3 provides further context for USGCRP projections of extraordinary sea level rise in the next 25 years.

More generally, NCA5’s inclusion of, and even focus on, implausible extreme scenarios supports projections of alarming impacts that are very unlikely to be driven by anthropogenic warming.

7 CONFLATION OF NATURAL AND ANTHROPOGENIC CLIMATE CHANGES

NCA5’s Glossary defines “climate change” as a change in climate for any reason. This is technically correct, but at variance with the (now) popular perception of all climate changes being anthropogenic. The distinction is not academic- it is central both to attribution questions and to projections, since anthropogenic changes would respond to mitigation, while natural changes are unavoidable.

The discussion on NCA5 page 2-4 begins “Human activities are changing the climate”, then goes on to list evidence for anthropogenic GHG emissions and climate warming. The next paragraph begins “Climate change is happening now in the United States. Including Alaska, the continental US has been warming about 60% faster than the planet as a whole since 1970.” In context the implication is that the warming of CONUS faster than the planetary average is an effect of GHG emissions. But it is an artifact of the Earth’s surface being 70 percent ocean. Since the ocean warms more slowly than land, comparison of any land surface outside the tropics with the global average would show the land surface to be warming faster than the global average, regardless of the cause of the warming.

The same page goes on to say “Climate change is already affecting people in the United States. Extreme heat was estimated to be responsible for more than 700 deaths per year between 2004 and 2018 although some estimates put heat-related mortality closer to 1,300 deaths annually.” But extreme heat, whether natural or not, has always been a risk to human health. As to trends, the data show that adaptation has caused the mortality burden of extreme heat to drop substantially in recent decades (CWG25 Section 10.3.1).

Consider also the NCA5 statement on precipitation that we cited in Section 3.2:

Many eastern regions of the country are getting wetter (Figure 2.4). Average annual precipitation from 2002-2021 was 5%-15% higher relative to the 1901-1960 average in the central and eastern US, a trend attributable to climate change.

The attribution is superfluous because the statement is a tautology by NCA5's definition of climate change. But its gratuitous inclusion effectively attributes the observed trend to greenhouse gas emissions.

Exploitation of the ambiguity in "climate change" is endemic to NCA5. The NASEM review (pp. 23-24) commented on this problem as follows:

The draft NCA5 report frequently describes "change" but does not consistently distinguish between natural variability and climate change. This lack of clarity can be misleading for the reader by creating the misconception that some impacts that are the result of the combination of natural variability and climate change are instead solely due to climate change... it is important for NCA5 authors to accurately identify the multiple drivers of change (including global change), in addition to climate change, and accurately attribute impacts. Clearly describing impacts due to natural variability, climate change, or a combination of the two is important not only for informing policy decisions, but also for building public understand and trust in the report's messages. Climate change and natural variability should be clearly defined in the glossary and natural variability could be introduced in chapter introductions when the concept is important for understanding key messages.

This could have been easily addressed by reserving the term "climate change" for anthropogenic changes and using "climate variability" for natural changes. But the NCA5 authors seemingly ignored their recommendation.

A separate but related issue is use of the term "climate change" to refer to increases in socioeconomic vulnerabilities that have anthropogenic but non-GHG-related causes. NCA5 page 1-19 states "Climate change exacerbates inequalities." But the issue discussed is the negative correlation between neighborhood-level income and land surface temperatures (LST) in urban areas. To the extent the correlation is real the most likely explanation is that low-income households concentrate where housing is less expensive, which may be in neighborhoods with less nearby parkland and tree cover, which has nothing to do with CO₂ emissions. Similarly the NCA5 makes repeated reference to the Billion Dollar Disaster dataset which is dominated by trends in population and economic growth, as we discussed in CWG25 Section 10.2.

8 SUMMARY EVALUATION OF NCA5 AND RECOMMENDATIONS FOR NCA6

This chapter summarizes our evaluation of NCA5 relative to OSTP's charge: whether NCA5 (1) complied with the USGCRP's statutory obligation; (2) adheres to the core tenets of Gold Standard Science; and (3) can suitably inform federal climate and energy policy. The points made in this summary analysis refer to specific sections of this report as well as to the CWG25 report.

8.1 Compliance with USGCRP's statutory obligation

As cited in Section 1.2 of this report, the Global Change Research Act requires an assessment that:

- (1) integrates, evaluates, and interprets the findings of the [Global Change Research] Program and discusses the scientific uncertainties associated with such findings;
- (2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and
- (3) analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

We deem NCA5 to have fallen short when evaluated against these criteria because of the following major shortcomings (each is detailed in the chapters cited):

- Inadequate assessment of the relevant topics in climate science and the hazard components of climate impacts (such as hurricanes and floods). NCA5 instead focuses on evaluation of societal vulnerabilities (such as flood infrastructure, access to air conditioning, etc.), “Climate Action,” and policy recommendations with a social justice emphasis (Section 1.2).
- Overconfidence in conclusions and inadequate assessment of uncertainties (Section 3.1.5)
- Inadequate discrimination between natural and human-induced causes of trends and impacts (Chapter 7)
- Inadequate analysis of climate trends by relying on short time periods (Chapter 6)
- Uncritical evaluation of emission scenarios and climate simulations in making projections for the next 25 to 100 years (Chapter 6; Section 3.2.1 and Chapter 5 of CWG25).

8.2 Adherence to the tenets of Gold Standard Science

With respect to the tenets of Gold Standard science listed in Section 1.2 of this report, we have identified the following major shortcomings in NCA5:

- **Lack of reproducibility.** In the few examples that we examined closely, we identified an instance where we could not reproduce the findings of the NCA5, a task that should require only rudimentary data analysis (Section 4.1)
- **Lack of transparency.** In many instances, the Traceable Account fails to justify the Key Finding. Metadata was not readily accessible. (Chapter 5)
- **Inadequate communication of error and uncertainty.** The Traceable Account for each Key Message provides a section on Major Uncertainties and Research Gaps; most of the accounts that we examined were superficial and uninformative. (Chapter 5)
- **Not skeptical of findings and assumptions.** The main text of the chapters is, with few exceptions, not skeptical of its findings and assumptions. (Chapters 3, 5)
- **Some hypotheses and Key Messages are not falsifiable.** Key Message 13.4 is but one of many examples: “Equitable Distribution of Transportation Trade-offs and Benefits Requires Community Involvement.”
- **Failure to acknowledge benefits** of warming and additional atmospheric CO₂ (CWG25 Section 2.1, Chapter 9)
- **Inadequacy of the peer review process.** The review of the NCA5 Third Order Draft by National Academies of Science, Engineering and Medicine (NASEM) identified some of the deficiencies we have noted, but the NCA5 authors were not obligated to adopt the NASEM recommendations. More importantly, we’ve identified many other deficiencies in NCA5; the NASEM review did not point them out and thus lacked the rigor expected of NASEM reports. (Section 1.4, Chapter 7)

8.3 Suitability for informing Federal climate and energy policy

We assess that the selection and presentation of information in NCA5 makes it an unreliable basis for U.S. climate and energy policymaking. For each of the elements of knowledge characterization suitable for risk management listed in Section 1.3, here are specific examples where NCA5 falls short:

- The degree to which the assumptions made are reasonable/realistic based on background knowledge
 - NCA5 focused on implausibly extreme scenarios for emissions and sea level rise scenarios and made policy recommendations without adequate consideration of the costs
- The degree to which data/information exists and are reliable and relevant
 - NCA5's assumptions about model reliability, and its use of short time periods for analysis, does not support its high-confidence conclusions
- The degree to which there is disagreement among experts, including those from different environments or academic fields
 - While NCA5 was an interdisciplinary effort, the concerns we have raised all point to a failure to canvass or communicate the full range of evidence including data and research findings that speak against Key Messages.
- The degree to which the phenomena involved are understood and accurate models exist
 - NCA5 is not appropriately skeptical of the ability of climate models to attribute the causes of warming and extreme events or to project future climates
- The degree to which the knowledge has been thoroughly examined with respect to unknown knowns
 - A major NCA5 shortcoming is its dismissal of natural climate variability in many contexts where it should have been a major consideration

NCA5 is also problematic for informing policy because its hyperbolic language promotes alarm and advocates for specific policies without proper analysis of marginal costs and benefits. In recent decades, climate science has engendered passion and emotion. Indeed, some younger climate scientists have gone into the field to "save the planet." The NASEM Review of the NCA5 underscores the endemic nature of this problem - their review appears to be written by authors who share many of the biases of the NCA5 team, with an inordinate focus on social and policy issues. It is then not surprising that objectivity can suffer when climate scientists communicate their understanding to non-experts. Further, the field of climate science has been politicized by NetZero mandates. This lack of objectivity usurps the public's right to make informed choices and undermines their confidence in the scientific enterprise.

Philip Handler, President of the National Academy of Sciences, identified the problem forty-five years ago in an [editorial](#) that still resonates:

Difficulty arises in the scientific community from confusion of the role of scientist *qua* scientist with that of scientist as citizen, confusion of the ethical code of the scientist with the obligation of the citizen, blurring the distinction between intrinsically scientific and intrinsically political questions. When scientists fail to recognize these boundaries, their own ideological beliefs, usually unspoken, easily becloud seemingly scientific debate.

8.4 Recommendations for NCA6

While we have assessed NCA5 to be scientifically inadequate and unsuitable as a basis for decision-making, one can imagine a different National Climate Assessment that meets statutory and policymaker requirements. The goal should be not to persuade, but to impart understanding by being objective, transparent and complete. A suitable NCA would be an important complement to IPCC assessments to the extent that its analysis and conclusions differed from the oracular “consensus” of the IPCC reports and additional topics are addressed. Such a report would promote a more open scientific discussion and a more informed policy debate.

We recommend that the NCA6 have a narrower scope than NCA5, refocusing on climate science, including natural climate variability, with topics to include:

- How the climate has changed in the past. The U.S. has the best and longest meteorological records and they should be examined and displayed in their entirety. Trend analyses should include longest periods available and employ suitable statistical methods. Local paleoclimate data should be considered where available. Analysis should demonstrate not only how the climate has varied and changed, but also regional heterogeneity. Standard, easily understandable metrics should be employed.
- The range of climatic and weather conditions, including extremes, that have occurred in the past and can reasonably be expected to occur in U.S. regions over the near future.
- A critical survey of current global and regional modeling capabilities and their suitability for regional impact assessments and projections. This would include an assessment of their ability to reproduce observed changes. It should also discuss alternative methods for generating projections and forecasts on regional and decadal scales, along the lines of Chapter 10 of the IPCC AR6 WGI Report.
- Assessment of the impacts of recent historical climate variability and change on ecosystems and society. Where long-term data indicate a detectable regional change, regional projections can be made for the period 2030-2050. Emissions scenarios exceeding RCP4.5/SSP2-4.5 and ECS values exceeding 4°C should not be used. Regional projections to 2100 have no credibility at this time.

It is important that climate projections be assessed in context of current science capabilities. The pressures toward spatially or temporally precise projections should be resisted as the current models are nowhere up to the task (an example is discussed in CWG25 Section 5.8). In that light, the many pages of NCA5 devoted to projected regional and sectoral impacts have little value.

Given the substantial deficiencies in NCA5 that we have identified, along with the endemic bias of the climate community towards alarmism and policy advocacy, producing an objective NCA6 report with the current NCA organizational construct would be a challenge. A NASEM review could help, but only if the selected participants reflect full viewpoint diversity and do not simply mirror the assumptions and biases of past NCA teams. We regard the CWG25 report to be a good start on NCA6 in terms of scope and objectivity, including adherence to the tenets of Gold Standard Science.

More broadly, we recommend a rewrite of the Global Change Research Act. The current mandate is vague and off point, allowing successive NCA teams to interpret the mandate as they see fit. Moreover, it is becoming increasingly clear that current and foreseeable models are not fit-for-purpose to describe regional climates, let alone usefully project them for 25 and 100 years. Further, the use of the term “global change” is ambiguous and outdated.

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Emergent constraints on equilibrium climate sensitivity in CMIP5: do they hold for CMIP6?
Earth System Dynamics 11 1233-1258 <https://doi.org/10.5194/esd-11-1233-2020>

APPENDICES

APPENDIX 1: Charge to the review

ABOUT THE AUTHORS

[Insert updated bios]

John Christy
Ross McKittrick

July 3, 2025

Supplement to NCA5 Critique: Examining the reproducibility of NCA5 claim of extreme precipitation trends

NCA5 states (p. 2-18):

Rainfall is becoming more extreme

Since the 1950s, there has been an upward trend in heavy precipitation across the contiguous US. This increase is driven largely by more frequent precipitation extremes, with relatively smaller changes in their intensity.

We attempted to verify this statement using long term U.S. precipitation records for the three regions discussed in CWG25 Section 6.4 (Pacific Coast, Southeast and Northeast) supplemented with the Midwest. We applied the methodology of McKittrick and Christy (2019), namely linear OLS trends with standard errors computed using the method of Vogelsang and Franses (2007) which is robust to general forms of serial correlation. Data are available at McKittrick and Christy (2025; NE, SE, PC) and Christy (2025; MW). Methods as described in McKittrick and Christy (2019), code available at McKittrick and Christy (2025).

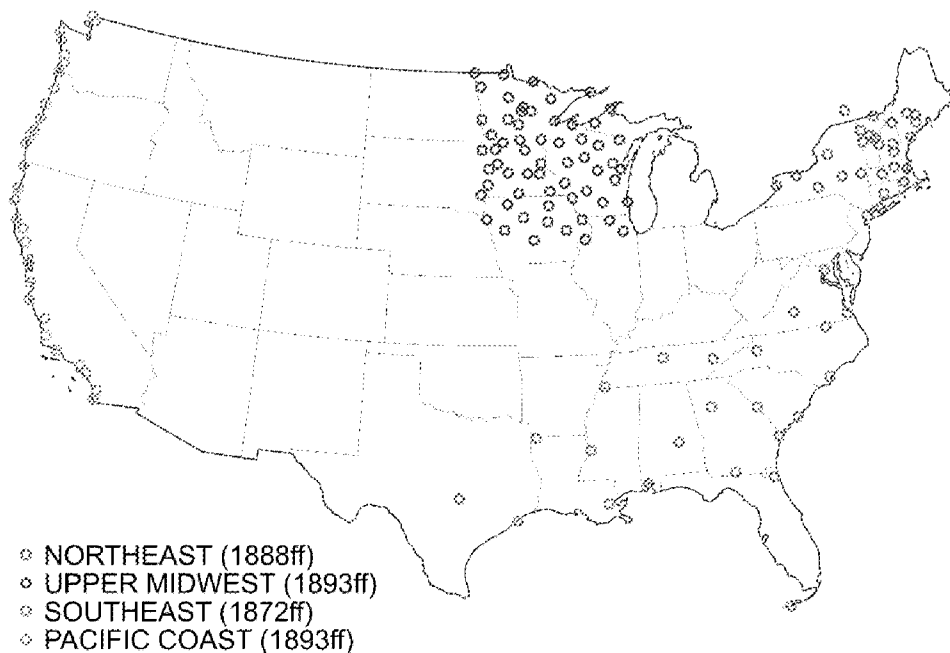


Figure S1: Stations used in the following analyses

In the Tables that follow the result codes are:

(-) neg insignificant, -- neg significant, (+) pos insignificant, ++ pos significant.

The Table columns are:

Column 1: Measure

Column 2: Number of stations in that region

Column 3: Count of stations exhibiting a significant positive trend

Column 3: Count of stations exhibiting a significant negative trend

Column 5: Characteristic of region-wide trend

PACIFIC COAST

Since 1893:

	No. stns	+ trends	- trends	region
1-day total	29	0	1	(-)
2-day total	29	0	1	(-)
Avg on non-zero days	29	0	9	--
Variability	29	1	0	(+)
Annual max	29	2	1	(+)
Number of 99 th pct exceedances	29	1	0	(-)

Since 1950:

	No. stns	+ trends	- trends	region
1-day total	29	0	1	(-)
2-day total	29	0	1	(-)
Avg on non-zero days	29	0	4	(-)
Variability	29	2	3	(-)
Annual max	29	6	3	(-)
Number of 99 th pct exceedances	29	2	1	(-)

Since 1980:

	No. stns	+ trends	- trends	region
1-day total	29	0	0	(-)
2-day total	29	0	0	(-)
Avg on non-zero days	29	0	1	(-)
Variability	29	0	0	(-)
Annual max	29	2	1	(-)
Number of 99 th pct exceedances	29	0	0	(+)

SOUTHEAST

Since 1873:

	No. stns	+ trends	- trends	region
1-day total	24	1	1	(+)
2-day total	24	1	1	(+)
Avg on non-zero days	24	7	2	(+)
Variability	24	1	0	(+)
Annual max	24	2	0	(+)
Number of 99 th pct exceedances	24	5	0	(+)

Since 1950:

	No. stns	+ trends	- trends	region
1-day total	24	5	0	++
2-day total	24	5	0	++
Avg on non-zero days	24	5	1	++
Variability	24	6	0	++
Annual max	24	4	0	++
Number of 99 th pct exceedances	24	4	0	(+)

Since 1980:

	No. stns	+ trends	- trends	region
1-day total	24	5	0	(+)
2-day total	24	5	0	(+)
Avg on non-zero days	24	5	1	(+)
Variability	24	3	0	(+)
Annual max	24	4	0	(+)
Number of 99 th pct exceedances	24	4	0	(+)

MIDWEST

Since 1893:

	No. stns	+ trends	- trends	region
1-day total	61	23	0	++
2-day total	61	23	0	++
Avg on non-zero days	61	2	12	(+)
Variability	61	12	0	++
Annual max	61	9	0	(+)
Number of 99 th pct exceedances	61	10	0	(+)

Since 1950:

	No. stns	+ trends	- trends	region
1-day total	61	28	2	++
2-day total	61	28	2	++
Avg on non-zero days	61	11	1	++
Variability	61	16	0	(+)
Annual max	61	8	0	(+)
Number of 99 th pct exceedances	61	19	0	++

Since 1980:

	No. stns	+ trends	- trends	region
1-day total	61	6	1	(+)
2-day total	61	6	1	(+)
Avg on non-zero days	61	8	2	(+)
Variability	61	5	1	(+)
Annual max	61	0	1	(+)
Number of 99 th pct exceedances	61	5	3	(-)

NORTHEAST

Since 1888:

	No. stns	+ trends	- trends	region
1-day total	27	12	0	++
2-day total	27	12	0	++
Avg on non-zero days	27	7	1	(+)
Variability	27	4	0	(+)
Annual max	27	3	0	(-)
Number of 99 th pct exceedances	27	5	0	(+)

Since 1950:

	No. stns	+ trends	- trends	region
1-day total	27	12	0	++
2-day total	27	12	0	++
Avg on non-zero days	27	7	1	(+)
Variability	27	4	0	(+)
Annual max	27	3	0	(-)
Number of 99 th pct exceedances	27	5	0	++

Since 1980:

	No. stns	+ trends	- trends	region
1-day total	27	10	1	++
2-day total	27	10	1	++
Avg on non-zero days	27	6	0	(+)
Variability	27	2	0	(+)
Annual max	27	1	0	(+)
Number of 99 th pct exceedances	27	1	1	++

Summary

Evaluating the NCA5 claim of an increase in heavy precipitation since 1950 across the CONUS, we find that we cannot reproduce it as stated. There is no evidence of an upward trend in rainfall or heavy precipitation (annual maximum or 99th percentile exceedances) in the Pacific Coast region and only mixed evidence in the Midwest and Northeast. The pattern is strongest in the Southeast. In all cases, however, only a few stations in each region exhibit statistically significant trends. Also in all cases, including the Southeast, the trends weaken in the post-1980 interval which suggests the trend is not tied to greenhouse gases. Furthermore, in no case is there a significant upward trend in the annual maximum or 99th percentile exceedances over the whole sample period back to the late 1800s.

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From: Judith Curry <curry.judith@gmail.com>
Sent: Sunday, July 13, 2025 3:12 PM
To: Ross McKittrick
Cc: Steven Koonin; John Christy; Roy W. Spencer; Travis Fisher; Josh Loucks; Seth Cohen
Subject: Re: NCA5 progress
Attachments: NCA5Review Curry.docx

see attached for a shorter, desnarked version of NCA5 for you to consider. I didn't do track changes, its clean text

On Sun, Jul 13, 2025 at 10:55 AM Ross McKittrick <ross.mckittrick@gmail.com> wrote:
Steve- this is the most recent version I have. There is also a Supplement on precip trends.

On Sat, Jul 12, 2025 at 6:18 PM Steven Koonin <steven.koonin@gmail.com> wrote:

Ross- Can you send around the most recent version of the NCA5 review. I can't seem to identify it in the emails and would like to go through it again in the next few days.

SEK

From: Ross McKittrick <ross.mckittrick@gmail.com>
Sent: Friday, July 11, 2025 3:49 PM
To: John Christy <climateman60@gmail.com>
Cc: judith curry <curry.judith@gmail.com>; Roy W. Spencer <roywspencer@hotmail.com>; Steven Koonin <steven.koonin@gmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>; Josh Loucks <loucksj14@gmail.com>; Seth Cohen <seth.cohen@hq.doe.gov>
Subject: Re: NCA5 progress

John and I only appear in Section 4.1 as part of challenging the reproducibility of the NCA5 Key Message regarding precipitation. 2 of our 3 citations in the reference list are data archives which are there for transparency purposes.

On Fri, Jul 11, 2025 at 2:53 PM John Christy <climateman60@gmail.com> wrote:

Judy

I must be missing something. Our papers directly address the issues espoused by NCA5. We offer all the data and methods. Why should our work be suppressed?

John C.

Sent from my iPhone

On Jul 11, 2025, at 1:16 PM, judith curry <curry.judith@gmail.com> wrote:

We need to think about our audience who we want to reach and influence. We don't want this to be another salvo in the climate wars. But to rise above it and be hyper objective.

Sent from my iPhone

On Jul 11, 2025, at 10:07 AM, John Christy <climateman60@gmail.com> wrote:

Judy

... Christy, McKittrick and Koonin ... you could look at it this way: we're the only ones willing to stick our heads up when the bullets are flying and endure protracted battles with editors and reviewers. Publishing in journals in this "climate" takes its toll, and most folks with an objective side just give up. We would love to cite other authors who do these NCA5-type analyses using the proper methods ... there just aren't many out there. As you know, there's no profit (or funding) in fighting the climate establishment. However, please, let us know if you see something we've missed.

John C.

On Fri, Jul 11, 2025 at 11:21 AM Judith Curry <curry.judith@gmail.com> wrote:

Re 1.4 and TX, i suggest we incorporate these points briefly in existing chapters. The content of 1.4 is already covered in CWG, apart from the convoluted peer review issue. CWG adequately covers temperature extremes, we don't need more of that in NCA beyond length of temperature records. Re TX, might fit best in CWG attribution, but its too early for that I think.

In 8.3 Recommendations for NCA5, we should recommend an increased focus on predicting individual extreme events and communicating the forecast, rather than attributing them to whatever.

What i'm struggling with in the NCA5 critique is that if you read it without an author list, you would figure the authors are christy, mckitrick, koonin. This should be a relatively short, high-level critique and IMO we need to depersonalize this

On Fri, Jul 11, 2025 at 8:19 AM Ross McKitrick
<ross.mckitrick@gmail.com> wrote:

We seem to have stalled on iterating the NCA5 report. Here are the issues on the table:

1. Whether to drop Section 1.4

- my thinking is I like the idea of the section because it justifies why we would presume to critique a report that has already gone through 11 government agencies and a National Academies review. At the same time I think it could be shortened and made more effective with a different version of the Figure from CWG25. John if you can you send me the spreadsheet you used I'll propose a rewrite.

2. Do we include a case study of the Texas floods?

- What I like about that section is that it is a vivid example of how a document that could have provided useful info for disaster planners not only failed to do so, but it would have misdirected resources if they were to have relied on it. But it's easy to have 20/20 hindsight. Presumably somewhere in the US at this moment there are several potential weather-related hazards poised to cause death and destruction later this year, and the local authorities

are not ready for them. We need to explain what it would look like for an NCA to be a useful resource in that context. What say ye all?

3. Tidying

- I find the LLM critiques to be somewhat helpful in anticipating possible lines of attack, but they are overly algorithmic and often end up saying "they make a valid point but that's not the consensus so it's probably wrong." And it seems to have hallucinated about things we didn't even say. Still, it points to the need to guard against snark.

--



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Critique of the Fifth National Climate Assessment

EXECUTIVE SUMMARY	3
1 INTRODUCTION	4
1.1 ABOUT THIS REPORT	4
1.2 ABOUT THE NATIONAL CLIMATE ASSESSMENTS	4
1.3 STANDARDS FOR ASSESSING NCA PRODUCTS	5
1.4 WHEN PEER REVIEW FAILED	ERROR! BOOKMARK NOT DEFINED.
2 NCA5 OVERVIEW CHAPTER: HYPERBOLIC ADVOCACY LANGUAGE AND UNSCIENTIFIC TONE.....	6
3 OVERCONFIDENCE WHEN STATING CONCLUSIONS	7
3.1 INFLATED CERTAINTY LEVELS	7
3.2 OVERSTATING FINDINGS IN UNDERLYING SOURCES	9
3.3 TECHNICAL EXAMPLE: EMERGENT CONSTRAINTS	9
4 ARBITRARY AND AMBIGUOUS TREND ANALYSIS.....	10
4.1 AVERAGE AND EXTREME PRECIPITATION.....	11
4.2 HEATWAVES.....	11
5 INADEQUATE TRACEABLE ACCOUNTS.....	14
6 OVEREMPHASIS ON EXTREME SCENARIOS	16
7 CONFLATION OF NATURAL AND ANTHROPOGENIC CLIMATE CHANGES	18
8 SUMMARY EVALUATION OF NCA5 AND RECOMMENDATIONS FOR NCA6.....	19
8.1 COMPLIANCE WITH USGCRP'S STATUTORY OBLIGATION	19
8.2 ADHERENCE TO THE TENETS OF GOLD STANDARD SCIENCE	20
8.3 SUITABILITY FOR INFORMING FEDERAL CLIMATE AND ENERGY POLICY	20
8.4 RECOMMENDATIONS FOR NCA6.....	21
9 REFERENCES	22
APPENDICES.....	24
APPENDIX 1: CHARGE TO THE REVIEW	24
ABOUT THE AUTHORS.....	25

EXECUTIVE SUMMARY

This report critically evaluates the Fifth National Climate Assessment (NCA5), finding it an inadequate basis for climate and energy policies. A detailed review of the foundational chapters on climate science raises several key concerns:

Scientific Integrity

- An advocacy tone, particularly in the Overview chapter, that is inconsistent with scientific objectivity
- Framing climate as a morality play
- Endemic overconfidence when stating conclusions, including inflated certainty levels and overstatement of findings from underlying sources
- No mentions of dissent, disagreement, controversies, or tradeoffs

Flawed methodology

- Minimal discussion of observational inadequacies
- Use of short time periods for trend analyses; more generally lack of a consistent rule for choosing time scales
- Attribution is implied, not dissected
- Overemphasis on extreme scenarios for future emissions and sea level rise
- Inadequate traceable accounts to support key conclusions

Inadequate Review Process

- A review by the National Academy of Sciences, Engineering, and Medicine (NASEM) failed to challenge some fundamental flaws in NCA5
- The NCA5 authors failed to adopt some improvements recommended by NASEM

The report shows NCA5 to be a biased and incomplete picture of climate science that skews toward excessive climate risk. Consequently, NCA5 should not be used as basis for climate and energy policies.

Motivated optimism with an advocacy tone

Subtle advocacy with emphasis

Attribution is implied, not dissected

Framing climate as a morality play

Dissent is invisible

Minimal discussion of observational limitations

No mention of tradeoffs

1 INTRODUCTION

1.1 About this Report

This report responds to a request from the Office of Science and Technology Policy (OSTP) Director Michael Kratsios (reproduced in Appendix 1) that we assess the suitability of the Fifth National Climate Assessment (NCA5 2023) for informing climate and energy policies.

To conduct this assessment, we reviewed NCA5 itself, the National Academies of Science, Engineering and Medicine (NASEM) review of the Third Order NCA5 Draft, and the USGCRP responses to that review. We have drawn upon our long experience working on advisory reports, including for the NASEM, the Intergovernmental Panel on Climate Change (IPCC) and other organizations, as writers, reviewers and study leaders.

We find that NCA5 should not be relied on for policy making as it is an incomplete and misleading picture of our understanding of the changing climate and the risks it poses to the nation. NCA5 was selective and incomplete in its survey of climate science. Further, we have reviewed recent scientific developments in a separate report to Energy Secretary Wright (Climate Working Group 2025, herein denoted “CWG25”). The overall effect of the biases and omissions of NCA5 is an excessively dire picture of climate risk.

To support our finding, the following sections of this chapter provide some background on the National Climate Assessments and the standards by which we have assessed NCA5. Chapters 2 through 7 detail important ways in which NCA5 fails to meet those standards. Finally, Chapter 8 summarizes our evaluation of NCA5 and makes recommendations for NCA6.

1.2 About the National Climate Assessments

The U.S. Global Change Research Program (USGCRP) was established by Presidential Initiative in 1989 and mandated by Congress in the Global Change Research Act (GCRA) of 1990 to develop and coordinate “a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change.”

The National Climate Assessment (NCA) Reports evolved from the GCRA requirement to:

Prepare and submit to the President and the Congress an assessment which (1) integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings; (2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and (3) analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

The five NCA Reports to date have interpreted this mandate in different ways:

- NCA1 (2000) was a multidisciplinary effort to study and portray in regional detail the potential effects of human-induced global warming on the United States.

- NCA2 (2009) was a relatively short report that not only focused on the potential consequences of climate change but also sought to identify potential adaptation measures and identify the highest priorities for future research.
- NCA3 (2014) was an expanded effort that continued along the lines of NCA2, and was distinguished by a comprehensive review process, including a review by the National Academy of Sciences. NCA3 introduced a traceability analysis for each key finding, including a description of uncertainties.
- NCA4 (2017/2018) was a further expanded effort that was published in two volumes: I Climate Science Special Report (CSSR), and II Impacts, Risk, and Adaptation in the United States. This was the first NCA report to devote significant effort to assessing climate science.
- NCA5 (2023) returned to a single volume format, reducing discussion of climate science to a cursory two chapters, with continuing focus on regional and sectoral impacts of climate change. NCA5 expanded its remit to topics that are arguably outside the purview of the USGCRP, focusing on “Climate Action” and policy recommendations with a social justice emphasis.

These successive interpretations of the NCA are poorly aligned with the GCRA’s statutory requirements. Only NCA4 gives serious consideration to climate science, which receives the great majority of USGCRP funding, and even then NCA4 misrepresents some important points. Natural climate variability is essentially dismissed as unimportant in NCA4 and barely mentioned in NCA5 in most contexts, despite the mandate to include both human-caused and natural climate change. Most significantly, NCA5 has redirected the focus away from climate science and even the hazard elements of impacts, towards evaluation of societal vulnerabilities and advocacy for particular policy options, especially deployment of wind and solar power generation.

1.3 Standards for Assessing NCA Products

Beyond the statutory requirements stated above, another pertinent standard is President Trump’s executive order of May 23, 2025, Restoring Gold Standard Science. It enumerates some of the characteristics of good science, namely that it should be:

- i. reproducible;
- ii. transparent;
- iii. communicative of error and uncertainty;
- iv. collaborative and interdisciplinary;
- v. skeptical of its findings and assumptions;
- vi. structured for falsifiability of hypotheses;
- vii. subject to unbiased peer review;
- viii. accepting of negative results as positive outcomes; and
- ix. without conflicts of interest.

For an assessment of policy relevant science, it is also important to include statements about the strength of knowledge. The IPCC’s approach to assessing strength of knowledge is based on judgment of the available evidence and agreement among experts. But there are more sophisticated knowledge characterizations for risk management. Here are the elements according to Aven (2017):

- The degree to which the assumptions made are reasonable/realistic based on background knowledge

- The degree to which data/information exists and are reliable and relevant
- The degree to which there is disagreement among experts (including those from different environments or academic fields)
- The degree to which the phenomena involved are understood and accurate models exist
- The degree to which the knowledge has been thoroughly examined with respect to unknown knowns (issues that are known to matter but are ignored, such as, in this context, natural variability).

2 NCA5 OVERVIEW CHAPTER: ADVOCACY LANGUAGE AND UNSCIENTIFIC TONE

NCA5 Chapter 1, “Overview”, holds a prominent place in the Report since it summarizes the entire report and is the only section that many will read. Chapter 1 is marred by an activist tone, language that aggressively promotes mitigation policies, and motivated optimism. As such, this chapter adds an imprimatur of scientific authority to naïve and simplistic declarations of opinion about public policy. Some examples are presented here.

Chapter 1 opens as follows:

The more the planet warms, the greater the impacts. Without rapid and deep reductions in global greenhouse gas emissions from human activities, the risks of accelerating sea level rise, intensifying extreme weather, and other harmful climate impacts will continue to grow. Each additional increment of warming is expected to lead to more damage and greater economic losses compared to previous increments of warming, while the risk of catastrophic or unforeseen consequences also increases.

This statement presupposes that all warming is anthropogenic, that all warming is bad and causes economic damage, and that warming intensifies extreme weather. Such sweeping generalizations go well beyond what science has or can establish. The statement also refers to growing risks without reference to their magnitude – a small risk that grows may still be a small risk, and a large risk may be only incrementally worsened.

On the next page the Overview states:

Each additional increment of warming leads to greater risks [here it lists 7 key components of society including food security and the economy]... Without deeper cuts in global net emissions, climate risks to the US will continue to grow... Action to limit future warming and reduce risks can have near-term benefits and opportunities: low-carbon energy jobs, Improved air quality, Health benefits, Economic benefits...”

The authors write as if climate policy does not involve trade-offs and all measures to reduce future warming will be effective and beneficial. Neither the vast body of scholarship on climate science and economics, nor historical experience, support such simplistic claims (CWG25). Not every additional increment of warming leads to economic harms; in fact, NCA5 Chapter 19 acknowledges that there will also be benefits. Nor is climate policy guaranteed to benefit the economy; it could impose net costs. Such misleading statements are a disservice to policymakers.

Pages 8 and 9 of the Overview promote renewable energy options by noting, correctly, that the levelized costs of wind/solar generation have fallen sharply since 2010, and so offers this rationale for pursuing deep emission reductions:

Recent growth in the capacities of wind, solar, and battery storage technologies is supported by rapidly falling costs of zero- and low-carbon energy technologies, which can support even deeper emissions reductions. For example, wind and solar energy costs dropped 70% and 90%, respectively, over the last decade, while 80% of new generation capacity in 2020 came from renewable sources.

Yet it has long been known that intermittent renewables generation must be supplemented by dispatchable generation to meet grid reliability standards, and that doing so (e.g., through natural gas, fission, or storage) significantly increases the cost of electricity. Further, there are yet unmet synchronization challenges in electrical grids with heavy penetration of wind and solar generation. NCA5 fails to acknowledge these facts. But more importantly, we see no reason for NCA5 to be discussing renewable energy technologies and economics in the context of its mandate.

Page 17 of the Overview introduces the discussion of risks from extreme weather events by saying “Harmful impacts from more frequent and severe extremes are increasing across the country.” This creates the impression that extreme weather events are worsening and that disaster losses are driven by trends in extreme weather. While the section goes on to acknowledge that some of the increase is due to increases in the exposure and value of assets at risk, it then invokes the NOAA Billion Dollar Dataset as evidence of extreme weather getting worse. Scientists have shown that this is an invalid metric (CWG2025 Section 10.2) since it measures the growth of the economy not the frequency of extreme weather, and indeed NOAA has recently withdrawn the data product. Even though the dataset was still distributed by NOAA at the time of the NCA5, the report authors failed to assess it skeptically and see that it was unfit for the purpose of measuring climate trends.

Page 23 of the Overview states, in large font:

Climate changes are making it harder to maintain safe homes and healthy families; reliable public services; a sustainable economy; thriving ecosystems, cultures, and traditions; and strong communities.

It is pointless to try to evaluate this statement on scholarly grounds. This kind of language doesn’t belong in a scientific assessment report. Its prominent inclusion points not only to the willingness of NCA5 authors to promote alarm, but also the ineffectiveness of the review process in eliminating such statements.

3 OVERCONFIDENCE WHEN STATING CONCLUSIONS

3.1 Inflated certainty levels

Overconfidence in stating conclusions has been an endemic problem in NCA Reports. The authors frequently make sweeping generalizations without appropriate caveats or acknowledging uncertainties. The overconfidence begins with inflated language to describe certainty levels.

NCA5 uses specific terms to convey information about scientific confidence associated with important finds, observations and projections. The Front Matter of NCA5 states that

confidence in a finding is based on the type, amount, quality, strength, and consistency of evidence; the skill, range, and consistency of methods to detect, evaluate, attribute, and interpret climate trends; and the degree of agreement across scientific information sources.

Table 1 from the Front Matter provides calibrated language for confidence assessment:

Very high:	Strong evidence (established theory, multiple sources, well documented and accepted methods, etc.). High consensus
High:	Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.). Medium consensus
Medium:	Suggestive evidence (a few sources, limited consistency, methods emerging, etc.) Competing schools of thought.
Low:	Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.). Disagreement or lack of opinions among experts.

This terminology is obviously inflated: *high confidence* with just moderate evidence and medium consensus; *medium confidence* with only suggestive evidence and competing schools of thought. This inflation in terminology leads to overconfidence in conclusions.

Even with this inflated terminology, NCA5 further inflates the confidence level of many of its conclusions to well beyond what the IPCC has concluded with more thorough justification, and by incorrectly applying its own standards. An example is the conclusion about anthropogenic influence on climate change, arguably one of the most important scientific statements of the report.

Key Message 3.1 Traceable Account states:

There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have unequivocally caused *all* global warming observed over the industrial era.

while the corresponding statements from IPCC AR5 and AR6 are

AR5: It is *extremely likely* that *more than half* of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together. (IPCC, 2013)

AR6: The *likely* range of total human-caused global surface temperature increase from 1850–1900 to 2010–2019 is 0.8°C to 1.3°C, with a best estimate of 1.07°C. It is *likely* that well-mixed GHGs contributed a warming of 1.0°C to 2.0°C, other human drivers (principally aerosols) contributed a cooling of 0.0°C to 0.8°C, natural drivers changed global surface temperature by –0.1°C to +0.1°C, and internal variability changed it by –0.2°C to +0.2°C. It is *very likely* that well-mixed GHGs were the main driver of tropospheric warming since 1979.

The IPCC AR5 and AR6 statements provide likelihood assessments but not a confidence level. While NCA5 claims with *very high confidence* that fossil fuels have unequivocally caused *all* global warming, AR5 refers to “*more than half* of the observed warming” and AR6 provides a more nuanced statement that relates to a *likely* range of warming contributed to by human drivers.

3.2 Overstating findings in underlying sources

Although we did not do a detailed audit of NCA5's use of source material, spot checks suggest a pattern of overstatement.

Chapter 2 page 11 reports on an increase in precipitation in some areas and attributes it to "climate change":

Many eastern regions of the country are getting wetter (Figure 2.4). Average annual precipitation from 2002-2021 was 5%-15% higher relative to the 1901-1960 average in the central and eastern US, a trend attributable to climate change.

NCA5 attributes the claim to Knutson and Zeng (2018). But Knutson and Zeng did not say these things nor did they analyze this particular period. For 1981-2010 they cautioned that observed changes are consistent with natural variability, and they did not claim attributable trends were observed over the United States.

As another example of overstating findings, NCA5's Chapter 2 page 18 states

There is robust evidence that human-caused warming has contributed to increases in the frequency and severity of the heaviest precipitation events across nearly 70% of the US.

This is apparently attributed to Diffenbaugh *et al.* (2018) and Kirchmeier-Young and Zhang (2020). Diffenbaugh *et al.* presented ratios of observed occurrences of extreme events to simulated occurrence rates in CMIP6 models run with only natural forcings. They report that for 79% of the U.S., extreme rainfall events are currently more frequent than in simulations, and the ratio of occurrences will rise under future warming simulations. This is not "robust" evidence of anthropogenic influence since it requires readers to assume that climate models accurately simulate regional precipitation patterns, something that the IPCC AR6 states is uncertain (AR6 WGI SPM Box SPM 1.2, SPM Section C.1.3).

Kirchmeier-Young and Zhang used three global climate models to analyze extreme 1- and 5-day events in North America. They noted large differences among the three models in their simulated precipitation changes, and two of the three models failed to yield attribution for 5-day events for the North America mean. In other words, the models disagreed on whether the observed changes were anthropogenic. Both of the cited references utilized the implausible RCP8.5 scenario (Chapter 6 of this Report) and began their "historical" observational records only in 1961. Here again this is not "robust" evidence, it is merely suggestive, particularly since other studies have found natural variability to be predominant.

3.3 Example: Emergent constraints

Some of the overconfidence expressed by NCA5 arises by omitting discussion of counterevidence in the peer reviewed literature, ignoring dissent and disagreement. An example is the topic of "emergent constraints". NCA5 Chapter 3 page 17 invokes this concept to support its claim that key uncertainties in climate model projections have been reduced:

An approach to reduce uncertainty in climate change projections has matured over the past decade. It is known as "emergent constraints." The term refers to strong statistical relationships between highly uncertain future climate parameters and observable trends or variations in the current climate, along with a physical explanation of this relationship.

Emergent constraints appeared in the climate modeling literature as an attempt to tie climate model behavior to climate observations in hopes of generating insight into real-world equilibrium climate sensitivity to a doubling of carbon dioxide (ECS). Climate models exhibit a wide range of ECS values. The idea of emergent constraints is to examine whether the models with shared sensitivity values also share a common representation of some climate process (usually related to clouds) that might influence ECS. Suppose, for instance, that in low-ECS models the total cloud fraction in the tropics is strongly correlated with that in the southern midlatitudes, but in high-ECS models the correlation is weak. Then researchers could examine whether the observed correlation is strong or weak and draw a conclusion about which type of model, and therefore which ECS value, is more likely.

A problem in the emergent constraint literature is that there has been a proliferation of proposed correlations with little physical motivation. NCA5 alludes to this in the Traceable Accounts section (p. 3-40) but not in the main Chapter text. As shown by Schlund *et al.* (2020) many emergent constraints patterned on CMIP5 models (Coupled Model Intercomparison Project No. 5, used for the IPCC 5th Assessment Report) failed to work on CMIP6 models (used for the IPCC 6th Assessment Report). In other words, the observed correlations in CMIP5 models between ECS and cloud processes failed to show up in CMIP6 models, indicating that they were likely spurious rather than clues to physical processes governing the climate system. As a result, emergent constraints estimated on CMIP5 models *increased* the uncertainty of ECS, rather than decreasing it as intended and as claimed by NCA5.

Yet NCA5 described the use of emergent constraint analysis as an advance that reduced uncertainty of ECS and climate model projections (p. 3-38):

Emergent constraints have been widely applied to reduce the simulated spread in the climate feedbacks that shape climate sensitivity.

4 ARBITRARY AND AMBIGUOUS TREND ANALYSIS

CWG25 Chapter 6 discussed the need for care in the choice of time scale when making claims about trends in extreme weather. We provided examples from analysis of river flooding, heatwaves, and extreme precipitation to show how assertions about apparent trends based on short data sets fall apart when looking at longer versions of the same data sets. NCA5 uses varying time periods for trend analyses, especially in Chapter 2 (which is focused on trends), without explaining why shorter or longer intervals were chosen. For example, page 2-4 defines temperature trends with respect to the interval since the late 1800s whereas page 3-29 presents temperature trends over 1972-2021. Page 2-11 compares rainfall over the 2002-21 versus 1901-1960 intervals while page 2-18 uses the interval since the late 1950s to compute trends.

A further problem is that NCA5 uses term "trend" repeatedly without indicating if it is statistically significant (*i.e.* distinguishable from random variability); the ambiguity creates the impression all the observed changes were significant, but readers are left to speculate. All climate variables will, in principle, drift up or down over any particular time interval. Identifying the change as a trend

requires showing that it is statistically significant using a variance estimator suitable for the type of data being analysed. Of particular importance is choosing a method robust to serial correlation which is frequently present in climate data. Throughout Chapters 1 to 3, references are made to “trends” without explaining how they were computed. The exception was on page 1-19 which refers to urban temperature trends being calculated using the Theil-Sen estimator, although that method does not seem to have been used elsewhere. The one case where reference is made to statistical significance was on Page 2-9 referring to a trend in Atmospheric Optical Depth, but no explanation is given of how significance was determined. Page 2-19 refers to regional trends in droughts being “robust” but again fails to explain how the term was defined.

In this chapter when we refer to calculation of trends in precipitation, we use ordinary least squares to compute the linear trend over the entire sample length and we use the Vogelsang and Franses (2007) variance estimator which is robust to general forms of serial correlation.

4.1 Average and Extreme Precipitation

CWG25 Section 6.4 we presented analyses of updated data for the same locations (and many others), in all cases finding both considerable regional heterogeneity and that trends detectable on one time scale are often not detected on longer or shorter time scales. These findings argue against simple attribution of changes to anthropogenic influences.

NCA5 did not continue the NCA4 precedent of using the post-1901 interval as the time scale for its precipitation discussion. Instead it refers to changes “since the 1950s”; NCA5 Figure 2.8 suggests 1958 might be the intended start date. Under Key Message 2.2 “Extreme Events Are Becoming More Frequent and Severe” (p. 2-16) NCA5 states (p. 2-18):

Rainfall is becoming more extreme
Since the 1950s, there has been an upward trend in heavy precipitation across the contiguous US. This increase is driven largely by more frequent precipitation extremes, with relatively smaller changes in their intensity.

In addition to our concerns that inferences about trends are contingent on choice of time scale, if the intended meaning of this statement is that positive and significant trends are found in heavy precipitation events across CONUS we cannot reproduce it. Details of our analysis can be found at [LINK TO BRIEF WRITEUP ON THIS](#) can we just reference CWG HERE

Based upon our analysis, the following is a more accurate summary of what U.S. precipitation data show.

There are regionally heterogeneous changes in average and extreme precipitation. Positive trends in annual average rainfall and extreme events (defined either as the annual maximum or the number of exceedances of the 99th percentile value) are generally weak or non-existent when looking at samples exceeding 130 years in length. Significant trends can be found when beginning the sample in the 1950s although in most cases the trends weaken and become insignificant when looking at the post-1980 interval. This argues against attribution of changes in precipitation to anthropogenic warming.

4.2 Heatwaves

In contrast to NCA5, NCA4 examined heat extremes across the entire 20th century, pointing out that peak heat wave activity was reached in the 1930s and has decreased since then, and that recent increases are confined to areas west of the Rockies. NCA4 stated:

[The] warmest daily temperature of the year increased in some parts of the West over the past century, but there were decreases in almost all locations east of the Rocky Mountains. In fact, all eastern regions experienced a net decrease, most notably the Midwest (about 2.2°F [1.2°C]) and the Southeast (roughly 1.5°F [0.8°C]).

Since the mid-1960s, there has been only a very slight increase in the warmest daily temperature of the year (amidst large interannual variability). Heat waves (6-day periods with a maximum temperature above the 90th percentile for 1961–1990) increased in frequency until the mid-1930s, became considerably less common through the mid-1960s, and increased in frequency again thereafter. As with warm daily temperatures, heat wave magnitude reached a maximum in the 1930s. (NCA4 pp. 190-191)

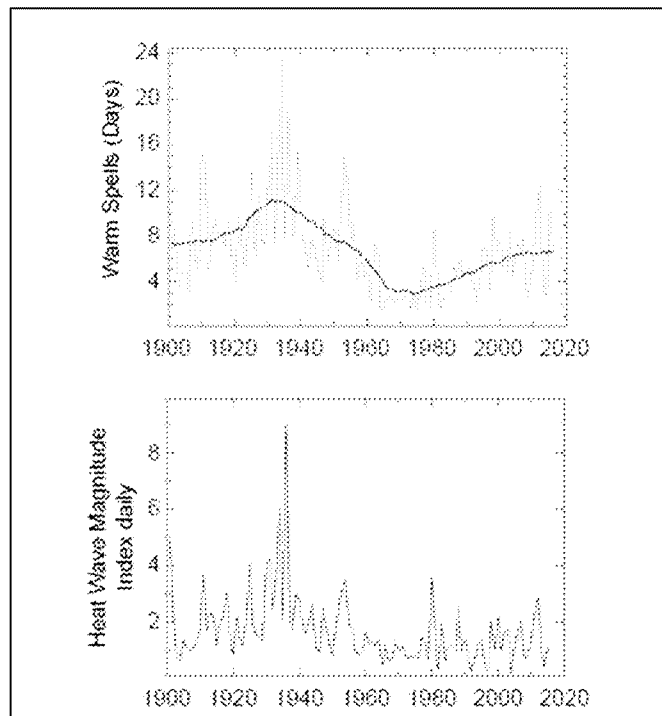


FIGURE 3. U.S. Heat waves since 1900. Reproduction of NCA4 Figure 6.4

Contrast this careful and factual language from NCA4 with NCA5 Key Message 2.2: “Extreme Events Are Becoming More Frequent and Severe.” This blanket statement is followed by NCA5 Figure 2.7 (reproduced as Figure 4 below) which shows the number of hot days, cold days and warm nights (respectively in panels a—c) over the period 2002-2021 compared to 1901-1960. [Presumably these are annual counts, although not stated in the caption.]

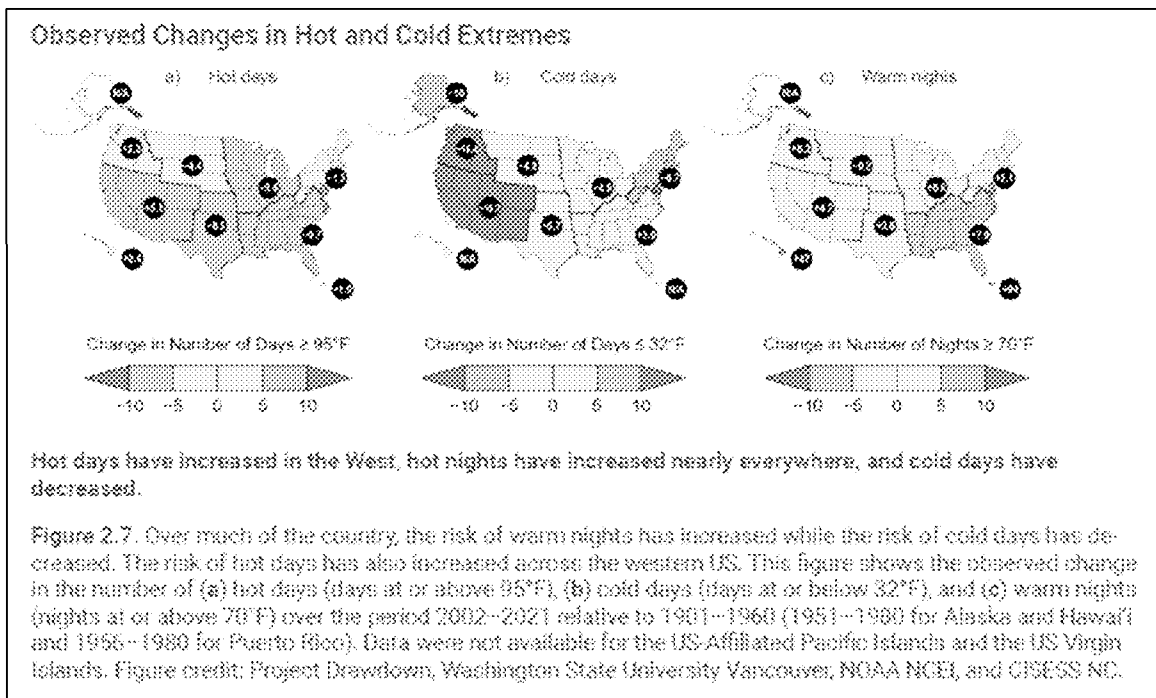


FIGURE 4: Reproduction of NCA5 Figure 2.7.

Close inspection shows that this figure actually contradicts the NCA5 Key Message with respect to heatwaves and instead reinforces the position of NCA4. Notwithstanding Key Message 2.2, the leftmost panel in NCA5 Figure 2.7 above shows that over most of CONUS the number of extreme heat days has *decreased* in recent decades compared to the prior century.

The accompanying discussion in NCA5 becomes convoluted as it appears to be aimed at supporting the Key Message despite the contrary evidence. NCA5 Chapter 2 elaborates on Key Message 2.2 by stating (page 16):

Observations show an increase in the severity, extent, and/or frequency of multiple types of extreme events. Heatwaves have become more common and severe in the West since the 1980s (*high confidence*).

But while it mentions the increase in hot days in the West, it fails to mention the decrease everywhere east of the Rockies. On the next page (page 17) it raises the comparison to the 1930s and then switches to discussing global counts:

By some measures, the most extreme heatwaves on record in the United States occurred during the Dust Bowl era of the 1930s. ... Globally such heatwaves are becoming more frequent, and in recent decades the western United States has been following those trends.

The reference to a global trend seems to be an attempt to tie heatwaves to anthropogenic climate change. But the obvious question, unaddressed by NCA5, is why one region follows the global pattern of increasing heatwaves while most of the country is trending in the opposite direction. These issues are addressed in Chapter 6 of CWG25, demonstrating that the range and magnitude of extreme temperatures are driven more by natural variability than by the small anthropogenic forcing. The analysis in CWG25 shows that for both (a) hot days ($\geq 95^{\circ}\text{F}$) and (b) number of days in heatwaves, the current decade is no hotter than a century ago in the U.S. Thus, the NCA5 claim that “multiday

heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades,” is simply false when expanding the temporal and spatial domains to encompass all available data (Chapter 6 and Figure 6.3.6 of CWG25).

NCA5 then pointed to the dramatic Pacific Northwest heatwave of 2021. CWG2025 Section 8.6.1 discussed this event in detail, reviewing the multiple peer reviewed studies that explained the unusual meteorological context was unrelated to human-caused climate change, a point omitted from the NCA5 discussion.

NCA5 finally addresses the declining heatwave trend in CONUS east of the Rockies but attempts to reframe it by focusing on urban warm spells.

[The] number of very hot days has actually decreased across the central and eastern regions due to summer cooling trends in the region (Figure 2.7; Ch. 22). This does not, however, mean the central and eastern US are not affected by heat. The impacts of extreme high temperatures are more severe if such conditions persist for several days, and overall, multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades. Across 50 large US cities, the US Global Change Research Program heatwave indicator (<https://www.globalchange.gov/indicators/heat-waves>) shows that the average number of heatwaves has doubled since the 1980s, and the length of the heatwave season has increased from about 40 days to about 70 days.

We discussed this part of NCA5 in CWG25 Section 6.3. The figure referenced by NCA5 uses a short time period which begins in the 1960s, the coldest decade in the last 100 years, thus suppressing any comparison to the 1930s. Further, nighttime temperatures in urban areas have increased faster than daytime temperatures (which NCA5 acknowledges), but this is a signature of urban heat islands and not a good metric of climate change. CWG25 found that the occurrence of hot days ($\geq 95^{\circ}\text{F}$) has recently increased in the West, but declined in the remainder of the country, and in the nationwide average, since 1899.

5 INADEQUATE TRACEABLE ACCOUNTS

NCA3 began the practice of including a section on Traceable Accounts at the end of each chapter. This is the description from NCA5:

Each chapter concludes with a section entitled Traceable Accounts, which provides information on the overall process used to develop the chapter as well as a separate Traceable Account section for each Key Message. These Traceable Accounts describe the supporting evidence behind each Key Message, the process and rationale authors used in reaching their conclusions, and the author team’s expert assessment of the confidence in and, where applicable, likelihood of these conclusions. As such, Traceable Accounts provide information about the state of the science, document sources of uncertainty, identify research gaps, and allow traceability to data and resources.

The Traceable Accounts for each Key Message includes the following sections:

- Description of Evidence Base
- Major Uncertainties and Research Gaps

- Description of Confidence and Likelihood

The Traceable Accounts could have addressed the statutory requirement that the NCA discuss scientific uncertainties. They could also help satisfy the Executive Order for Restoring Gold Standard Science by addressing reproducibility, transparency, communication of error and uncertainty, and skepticism of findings and assumptions. However, the Traceable Accounts in NCA5's Chapters 2 and 3 are uneven, often superficial and uninformative.

An example of a deficient Traceable Account is NCA5's Key Message 2.2: "Extreme Events are Becoming More Frequent and Severe". The "Description of the Evidence Base" offers two paragraphs, the first summarizing the findings and the second generically describing the types of data that can be used for storms. "Major Uncertainties and Research Gaps" focuses on the uneven distribution across U.S. populations due to differences in exposure and vulnerability. The only limitations in data referred to are the lack of a long-term record of lightning and the lack of homogenized daily and hourly temperature data apart from reanalysis products.

But the most astonishing deficiency is in the "Description of Confidence and Likelihood." One of the statements in Key Message 2.2 is:

Hurricanes have been intensifying more rapidly since the 1980s (*high confidence*) and causing heavier rainfall and higher storm surges (*high confidence*).

The Description of Confidence and Likelihood includes the following statement:

Basic physical understanding and climate models both provide robust explanations for the links between climate change and observed changes in these extremes: this is why the authors also have high confidence that storms are delivering more rainfall and high confidence that storm surges are becoming higher.

No reference to journal publications or a specific data set is made anywhere in the chapter regarding hurricane-induced precipitation or storm surge to support this *high confidence* conclusion.

The Traceable Accounts for the various Key Findings of Chapter 3 have some substantial inconsistencies. Consider

Key Message 3-1: Human activities have caused global warming.

Confidence and Likelihood: "There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have *unequivocally* caused all global warming observed over the industrial era. There is also *very high confidence* that changes in natural climate drivers have had globally small and regionally variable long-term effects over this period."

The Uncertainties section addresses only uncertainties in radiative forcing by greenhouse gases, ignoring the great uncertainty in model response (CWG25 Chapters 4&5) In contrast, the Traceability Analysis of Key Message 3-4 ("Humans Are Changing Earth System Processes") raises the problem that relatively little is known about the role of natural variability at the regional scale. From its Description of Evidence Base:

In the last decade, there has been increasing recognition of the role of regional-scale natural variability in the past and future evolution of climate, as well as the fact that regional natural variability signals can be competitive with forced anthropogenic signals.

And from its Major Uncertainties and Research Gaps:

For example, the true natural variability of the climate system on decadal to centennial timescales could be larger than what we estimate from GCMs, which would further increase the irreducible uncertainty stemming from natural variability.

These statements are among the most scientifically credible in the entire NCA5 and they directly undercut the confidence assigned to Key Message 3-1.

There is also a generic problem in tracing NCA5's Traceable Accounts. The Front Matter of NCA5 states:

Each figure and some tables are accompanied by a metadata survey, which can be accessed in the online version of the report by clicking on the eyeball icon above the figure or table (see the table below for explanations of additional icons used throughout the report). The metadata survey describes data sources, figure or table development methods, copyright information, and other important documentation.

Clicking on the 'eyeball' icon does not reveal the metadata information; instead a "Contact Us" email appears, addressed to the USGCRP. This is an inadequate way to archive the metadata information.

In summary, the Traceable Analyses examined here, with few exceptions, fail to meet the stated objectives of the NCA.

6 OVEREMPHASIS ON EXTREME SCENARIOS

To respond to the GCRA mandate to "project major trends for the subsequent 25 to 100 years," NCA5 relies on projections of future climate change based on estimates of future emissions (the so-called SSP scenarios) and/or specified levels of radiative forcing (the RCP scenarios). For the most part, NCA5 uses scenarios developed for the IPCC Assessment Reports.

CWG25 Section 3.2.1 presented a critical assessment of past and current IPCC scenario envelopes, showing that they have tended to overshoot observed emissions. IPCC AR6 published in 2021 stated that "The likelihood of high-emission scenarios like RCP8.5 and SSP5-8.5 is considered low in light of recent energy sector developments." and that same year UN Climate Negotiators (COP) stopped using scenarios above 4.5.

NCA5 makes the following observations about the scenarios they use:

NCA5 authors were advised to assess the full range of scenarios available. (Front Matter)

Scenarios of future emissions and land-use change are developed as plausible alternatives, but no relative likelihood is attached to them. Some recent studies, however, have argued that

the highest scenario, SSP5-8.5, is no longer plausible without a reversal of current trends in the adoption of renewables and energy efficiency. (Key Message 3.3 Traceable Analysis)

Despite acknowledging the issue, NCA5 otherwise ignored the problem. A keyword search of NCA5 of mentions of RCP/SSP scenarios finds over 50% referred to the extreme emissions scenarios RCP8.5/SSP5-8.5. Further, nine NCA5 figures (5.2, 6.9, 7.4, 11.3, 14.6, 22.13, 22.19, 27.9, 29.13) included *only* the 8.5 scenarios.

The problem of relying on extreme scenarios is particularly acute for NCA5's sea level rise projections. The sea level rise scenarios used in NCA5 do not relate directly to the SSP emissions scenarios, but rather to specified amounts of sea level rise by 2100. Table 4 of NCA5's "Guide to Using this Report" reproduced below shows that Low relates to 0.3 m (0.98 feet), Intermediate-Low relates to 0.5 m (1.64 feet), Intermediate relates to 1.0 m (3.28 feet), Intermediate-High relates to 1.5 m (4.92 feet), and High relates to 2.0 m (6.56 feet).

Table 4. Descriptive Terms for Common Sea Level Rise Scenarios Used in NCA5						
Future global mean sea level rise and sea level rise along United States coastline are shown for five scenarios in feet (and meters), relative to a 2000 baseline. The US values shown in the right half of the table are averaged across the US coastal regions, including the contiguous US, Alaska, Hawaii, and the US-Affiliated Pacific Islands, and the US Caribbean. The national values shown in the table differ substantially from regional values. For example, sea level rise is higher in the Gulf Coast and lower or even negative in some parts of Alaska. In the next 30 years (2020–2050), sea level along the contiguous US coasts is expected to rise 0.92 feet (0.28 m), the same amount of sea level rise observed over the last 100 years (1920–2020). See Chapter 9 for regional sea level information. Adapted from Sweet et al. 2022.”						
Sea Level Rise Scenario Descriptor	Global Mean Sea Level			United States		
Year	2050	2100	2150	2050	2100	2150
Low	0.49 (0.15)	0.98 (0.3)	1.31 (0.4)	0.59 (0.18)	0.98 (0.3)	1.64 (0.5)
Intermediate-Low	0.66 (0.20)	1.64 (0.5)	2.62 (0.8)	0.75 (0.23)	1.64 (0.5)	2.95 (0.9)
Intermediate	0.92 (0.28)	3.28 (1.0)	6.23 (1.9)	0.89 (0.27)	3.28 (1.0)	6.89 (2.1)
Intermediate-High	1.21 (0.37)	4.92 (1.5)	8.86 (2.7)	1.12 (0.34)	4.92 (1.5)	8.86 (2.7)
High	1.41 (0.43)	6.56 (2.0)	12.14 (3.7)	1.38 (0.42)	6.56 (2.0)	12.46 (3.8)

TABLE 1: Reproduction of Table 4 from the Front Matter of NCA5

Considering only projections representing processes quantified with at least medium confidence, IPCC AR6 assessed global mean sea level projections for all emissions scenarios (including implausible extreme emissions scenarios) for 2100 to fall between 0.2 and 1.6 m (5th—95th percentile range). Nevertheless, the range of sea level rise scenarios considered by NCA5 extends to 2.0 m. Further, NCA5 fails to include plausible lower scenarios, such as 0.2 m cited by the IPCC, which also corresponds to the average rate of sea level rise over the past century.

Chapter 9 of NCA5 offers the following predictions of sea level rise:

“Under a range of potential global warming levels, average sea level along US coastlines is *likely* to be between 12 and 20 inches above 2000 sea levels in 2050 (Figure 9.2).”

The projected sea level rise values span from the Intermediate scenario to values slightly greater than the High scenario. They can be put into context by considering the observed global sea level rise from 2000-2024, which is only approximately 3.4 inches (0.28 feet). NCA5 is thus projecting a sea level rise during 2025 and 2050 that is 3.5 to 5.8 times the rate observed during 2000-2024, an exceedingly implausible outcome. Chapter 9 further states:

“Looking toward the future, an 11 inch (28 cm) average rise along the contiguous US coastline is expected by 2050 (relative to 2020), with a *likely* range of 9-13 inches.”

...

“There is *high confidence* and it is *likely* that sea levels will rise about 11 inches (likely range of about 9–13 inches) between 2020 and 2050”

In summary, NCA5 presents future sea level rise scenarios that are not directly relatable to either SSP/RCP emissions scenarios or to plausible global warming levels. The NCA5 scenarios include two that are higher than the 95th percentile for the extreme emissions scenario RCP8.5 and include hypothesized ice sheet processes in which there is low confidence. Projections to 2050 require rates of sea level rise from 2025 to 2050 that are more than triple the rate observed during 2000-2024. Further, NCA5 ascribes *high confidence* to these sea level rise projections. CWG25 Section 7.3 provides further context for USGCRP projections of extraordinary sea level rise in the next 25 years.

More generally, NCA5’s inclusion of, and even focus on, implausible extreme scenarios supports projections of alarming impacts that are very unlikely to be driven by anthropogenic warming.

7 CONFLATION OF NATURAL AND ANTHROPOGENIC CLIMATE CHANGES

NCA5’s Glossary defines “climate change” as a change in climate for any reason. This is technically correct, but at variance with the (now) popular perception of all climate changes being anthropogenic. The distinction is not academic- it is central both to attribution questions and to projections, since anthropogenic changes would respond to mitigation, while natural changes are unavoidable.

The discussion on NCA5 page 2-4 begins “Human activities are changing the climate”, then goes on to list evidence for anthropogenic GHG emissions and climate warming. The next paragraph begins “Climate change is happening now in the United States. Including Alaska, the continental US has been warming about 60% faster than the planet as a whole since 1970.” The implication is that the warming of CONUS faster than the planetary average is an effect of GHG emissions. But it is an artifact of the Earth’s surface being 70 percent ocean. Since the ocean warms more slowly than land, comparison of any land surface outside the tropics with the global average would show the land surface to be warming faster than the global average, regardless of the cause of the warming.

The same page goes on to say “Climate change is already affecting people in the United States. Extreme heat was estimated to be responsible for more than 700 deaths per year between 2004 and 2018 although some estimates put heat-related mortality closer to 1,300 deaths annually.” But extreme heat, whether natural or not, has always been a risk to human health. As to trends, the data show that adaptation has caused the mortality burden of extreme heat to drop substantially in recent decades (CWG25 Section 10.3.1).

Consider also the NCA5 statement on precipitation that we cited in Section 3.2:

Many eastern regions of the country are getting wetter (Figure 2.4). Average annual precipitation from 2002-2021 was 5%-15% higher relative to the 1901-1960 average in the central and eastern US, a trend attributable to climate change.

The attribution is superfluous because the statement is a tautology by NCA5's definition of climate change. But its gratuitous inclusion effectively attributes the observed trend to greenhouse gas emissions.

Exploitation of the ambiguity in "climate change" is endemic to NCA5. The NASEM review (pp. 23-24) commented on this problem as follows:

The draft NCA5 report frequently describes "change" but does not consistently distinguish between natural variability and climate change. This lack of clarity can be misleading for the reader by creating the misconception that some impacts that are the result of the combination of natural variability and climate change are instead solely due to climate change... it is important for NCA5 authors to accurately identify the multiple drivers of change (including global change), in addition to climate change, and accurately attribute impacts. Clearly describing impacts due to natural variability, climate change, or a combination of the two is important not only for informing policy decisions, but also for building public understand and trust in the report's messages. Climate change and natural variability should be clearly defined in the glossary and natural variability could be introduced in chapter introductions when the concept is important for understanding key messages.

This could have been easily addressed by reserving the term "climate change" for anthropogenic changes and using "climate variability" for natural changes. But the NCA5 authors seemingly ignored their recommendation.

A separate but related issue is use of the term "climate change" to refer to increases in socioeconomic vulnerabilities that have anthropogenic but non-GHG-related causes. NCA5 page 1-19 states "Climate change exacerbates inequalities." But the issue discussed is the negative correlation between neighborhood-level income and land surface temperatures (LST) in urban areas. To the extent the correlation is real, the most likely explanation is that low-income households concentrate where housing is less expensive, which may be in neighborhoods with less nearby parkland and tree cover, which has nothing to do with CO₂ emissions.

8 SUMMARY EVALUATION OF NCA5 AND RECOMMENDATIONS FOR NCA6

This chapter summarizes our evaluation of NCA5 relative to OSTP's charge: whether NCA5 (1) complied with the USGCRP's statutory obligation; (2) adheres to the core tenets of Gold Standard Science; and (3) can suitably inform federal climate and energy policy. The points made in this summary analysis refer to specific sections of this report as well as to the CWG25 report.

8.1 Compliance with USGCRP's statutory obligation

As cited in Section 1.2 of this report, the Global Change Research Act requires an assessment that:

- (1) integrates, evaluates, and interprets the findings of the [Global Change Research] Program and discusses the scientific uncertainties associated with such findings;

- (2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and
- (3) analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

We deem NCA5 to have fallen short when evaluated against these criteria because of the following major shortcomings (each is detailed in the chapters cited):

- Inadequate assessment of the relevant topics in climate science and the hazard components of climate impacts (such as hurricanes and floods). NCA5 instead focuses on evaluation of societal vulnerabilities (such as flood infrastructure, access to air conditioning, etc.), “Climate Action,” and policy recommendations with a social justice emphasis (Section 1.2).
- Overconfidence in conclusions and inadequate assessment of uncertainties (Section 3.1.5)
- Inadequate discrimination between natural and human-induced causes of trends and impacts (Chapter 7)
- Inadequate analysis of climate trends by relying on short time periods (Chapter 6)
- Uncritical evaluation of emission scenarios and climate model simulations in making projections for the next 25 to 100 years (Chapter 6; Section 3.2.1 and Chapter 5 of CWG25).

8.2 Adherence to the tenets of Gold Standard Science

With respect to the tenets of Gold Standard science listed in Section 1.2 of this report, we have identified the following major shortcomings in NCA5:

- **Lack of reproducibility.** In the few examples that we examined closely, we identified an instance where we could not reproduce the findings of the NCA5, a task that should require only rudimentary data analysis (Section 4.1)
- **Lack of transparency.** In many instances, the Traceable Account fails to justify the Key Finding. Metadata was not readily accessible. (Chapter 5)
- **Inadequate communication of error and uncertainty.** The Traceable Account for each Key Message provides a section on Major Uncertainties and Research Gaps; most of the accounts that we examined were superficial and uninformative. (Chapter 5)
- **Not skeptical of findings and assumptions.** The main text of the chapters is, with few exceptions, not skeptical of its findings and assumptions and does not mention dissent or disagreement. (Chapters 3, 5)
- **Some hypotheses and Key Messages are not falsifiable.** Key Message 13.4 is but one of many examples: “Equitable Distribution of Transportation Trade-offs and Benefits Requires Community Involvement.”
- **Failure to acknowledge benefits** of warming and additional atmospheric CO₂ (CWG25 Section 2.1, Chapter 9)
- **Inadequacy of the peer review process.** The review of the NCA5 Third Order Draft by National Academies of Science, Engineering and Medicine (NASEM) identified some of the deficiencies we have noted, but the NCA5 authors were not obligated to adopt the NASEM recommendations. More importantly, we’ve identified many other deficiencies in NCA5; the NASEM review did not point them out and thus lacked the rigor expected of NASEM reports.

8.3 Suitability for informing Federal climate and energy policy

We assess that the selection and presentation of information in NCA5 makes it an unreliable basis for U.S. climate and energy policy making. For each of the elements of knowledge characterization suitable for risk management listed in Section 1.3, here are specific examples where NCA5 falls short:

- The degree to which the assumptions made are reasonable/realistic based on background knowledge
 - NCA5 focused on implausibly extreme scenarios for emissions and sea level rise scenarios and made policy recommendations without adequate consideration of the costs
- The degree to which data/information exists and are reliable and relevant
 - NCA5's unjustified assumptions about model reliability, and its use of short time periods for analysis, does not support its high-confidence conclusions
- The degree to which there is disagreement among experts, including those from different environments or academic fields
 - While NCA5 was an interdisciplinary effort, the concerns we have raised all point to a failure to canvass or communicate the full range of evidence including data and research findings that speak against Key Messages.
- The degree to which the phenomena involved are understood and accurate models exist
 - NCA5 is not appropriately skeptical of the ability of climate models to attribute the causes of warming and extreme events or to project future climates
- The degree to which the knowledge has been thoroughly examined with respect to unknown knowns
 - A major NCA5 shortcoming is its dismissal of natural climate variability in many contexts where it should have been a major consideration

NCA5 is also problematic for informing policy because its hyperbolic language promotes alarm and advocates for specific policies without a proper risk analysis. The NASEM Review of the NCA5 underscores the endemic nature of this problem - their review appears to be written by authors who share many of the biases of the NCA5 team, with an inordinate focus on social and policy issues. It is then not surprising that objectivity can suffer when climate scientists communicate their understanding to non-experts. Further, the field of climate science has been politicized by NetZero mandates. This lack of objectivity usurps the public's right to make informed choices and undermines their confidence in the scientific enterprise.

Philip Handler, President of the National Academy of Sciences, identified the problem forty-five years ago in an [editorial](#) that still resonates:

Difficulty arises in the scientific community from confusion of the role of scientist *qua* scientist with that of scientist as citizen, confusion of the ethical code of the scientist with the obligation of the citizen, blurring the distinction between intrinsically scientific and intrinsically political questions. When scientists fail to recognize these boundaries, their own ideological beliefs, usually unspoken, easily becloud seemingly scientific debate.

8.4 Recommendations for NCA6

While we have assessed NCA5 to be scientifically inadequate and unsuitable as a basis for decision-making, one can imagine a different National Climate Assessment that meets statutory and policy maker requirements. The goal should be not to persuade, but to impart understanding by being objective, transparent and complete. A suitable NCA would be an important complement to IPCC assessments to the extent that its analysis and conclusions differ from the "consensus" of the IPCC

reports and additional topics are addressed. Such a report would promote a more open scientific discussion and a more informed policy debate.

We recommend that the NCA6 have a narrower scope than NCA5, refocusing on climate science, including natural climate variability, with topics to include:

- How the climate has changed in the past. The U.S. has the best and longest meteorological records and they should be examined and displayed in their entirety. Trend analyses should include longest periods available and employ suitable statistical methods. Local paleoclimate data should be considered where available. Analysis should demonstrate not only how the climate has varied and changed, but also regional heterogeneity. Standard, easily understandable metrics should be employed.
- The range of climatic and weather conditions, including extremes, that have occurred in the past and can reasonably be expected to occur in U.S. regions over the near future. The regional chapter for REGION that includes Texas only stated that
- A critical survey of current global and regional modeling capabilities and their suitability for regional impact assessments and projections. This would include an assessment of their ability to reproduce observed changes. It should also discuss alternative methods for generating projections and forecasts on regional and decadal scales, along the lines of Chapter 10 of the IPCC AR6 WGI Report.
- Assessment of the impacts of recent historical climate variability and change on ecosystems and society. Where long-term data indicate a detectable regional change, regional projections can be made for the period 2030-2050. Emissions scenarios exceeding RCP4.5/SSP2-4.5 and ECS values exceeding 4°C should not be used. Regional projections to 2100 have no credibility at this time.

It is important that climate projections be assessed in context of current science capabilities. The pressures toward spatially or temporally precise projections should be resisted as the current models are nowhere up to the task (an example is discussed in CWG25 Section 5.8). In that light, the many pages of NCA5 devoted to projected regional and sectoral impacts have little value.

Given the substantial deficiencies and bias in NCA5 that we have identified, producing an objective NCA6 report with the current NCA organizational construct would be a challenge. A NASEM review could help, but only if the selected participants reflect full viewpoint diversity and do not simply mirror the assumptions and biases of past NCA teams. We regard the CWG25 report to be a good start on NCA6 in terms of scope and objectivity, including adherence to the tenets of Gold Standard Science.

More broadly, we recommend a rewrite of the Global Change Research Act. The current mandate is vague and off point, allowing successive NCA teams to interpret the mandate as they see fit. Moreover, it is becoming increasingly clear that current and foreseeable models are not fit-for-purpose to describe regional climates, let alone usefully project them for 25 and 100 years. Further, the use of the term “global change” is ambiguous and outdated.

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APPENDICES

APPENDIX 1: Charge to the review

ABOUT THE AUTHORS

[Insert updated bios]

From: John Christy [climateman60@gmail.com]
Sent: 7/14/2025 7:25:12 PM
To: Judith Curry [curry.judith@gmail.com]
CC: Steven Koonin [steven.koonin@gmail.com]; Ross McKittrick [ross.mckittrick@gmail.com]; Roy W. Spencer [roywspencer@hotmail.com]; Travis Fisher [travis.scott.fisher@gmail.com]; Josh Loucks [loucksj14@gmail.com]; Seth Cohen [seth.cohen@hq.doe.gov]
Subject: Re: NCA5 progress

It seems to me that if CoPilot swims in a pool with lots of chaff and little wheat, it will be convinced that the chaff must be considered valid and therefore is unable to discern the correctness of arguments against the chaff. Included in the chaff are volumes of negative assertions against Ross, Roger, me etc. (don't know why Steve, Roy and Judy were left out.), so it assumes our contributions are suspect. Overall I think this exercise is quite valuable but it needs real humans to provide some adult supervision.

John C.

On Mon, Jul 14, 2025 at 1:23 PM Judith Curry <curry.judith@gmail.com> wrote:
Not clear what is meant by editorializing?

On Mon, Jul 14, 2025 at 11:17 AM Steven Koonin <steven.koonin@gmail.com> wrote:
Here's what COPilot has to say about Judy's desnarked version:

Here's a structured analysis of the **NCA5 Review** document (authored by Judith Curry and colleagues), focusing on four key dimensions: **scientific accuracy**, **tone**, **bias**, and **logical coherence**.

Scientific Accuracy

Strengths

- **Valid critiques of model sensitivity and emissions scenarios:** The report raises legitimate concerns about the plausibility of SSP5-8.5 and excessive reliance on high-end sea level projections. These reflect ongoing debates in the literature and are grounded in methodological caution.
- **Methodological concerns are substantive:**
 - Inconsistencies in time-series analysis and selective baselines (e.g. 1958 vs 1901) are rightly flagged as a statistical pitfall.
 - Emergent constraints critique aligns with studies (e.g. Schlund et al., 2020) that caution against overinterpreting spurious correlations.
- **Challenges attribution simplifications:** Points to cases where NCA5 presents strong attribution claims without robust methodological explanation—particularly on precipitation and heatwaves.

Limitations

- **Some critiques rely on selective counter-literature:** While the report references CWG25 and contrarian scientists (e.g. McKittrick, Christy, Pielke Jr.), it underrepresents the broader consensus literature and fails to engage with rebuttals to those views.
 - **Reproduction failures lack detail:** When stating inability to replicate NCA5's findings, such as trends in precipitation, the methodology is referenced but not fully shown—limiting reproducibility of the critique itself.
 - **Model criticisms overgeneralized:** Claims that current models are “not fit-for-purpose” for long-term regional projections ignore recent advancements in downscaling, probabilistic framing, and multi-model ensembles.
-

Tone

- **Formal but adversarial:** The report maintains a professional structure but frequently uses language that characterizes NCA5 as biased, ideological, or propagandistic (e.g., “hyperbolic advocacy,” “activist tone,” “naïve and simplistic”).
- **Occasional rhetorical overreach:** Phrases like “scientific malpractice,” “usurps the public’s right to informed choice,” or citing 1970s-era editorials suggest a broader normative agenda beyond empirical review.
- **Dismissive of policy framing:** The critique is sharply opposed to NCA5’s social justice themes and policy recommendations, labeling them extraneous or political, rather than engaging with their empirical basis (e.g., equity in heat exposure).

Bias and Framing

Category	Indicators
Source Selection	Prioritizes CWG25, skeptics of consensus science; under-cites mainstream climate literature
Framing Strategy	Positions CWG25 as scientific corrective to NCA5’s alleged ideological bias
Motive Attribution	Suggests mainstream climate scientists are motivated by fear, activism, or political mandates
Language Use	Uses emotionally and politically charged terms in what is framed as a scientific review

- **Binary worldview:** The document tends to frame climate discourse as either “Gold Standard Science” or ideological overreach, leaving limited room for middle-ground scientific pluralism.
- **Limited acknowledgment of uncertainty in contrarian claims:** While NCA5’s uncertainties are dissected in detail, competing claims (e.g., about historical heatwaves or CO₂ fertilization benefits) are presented with stronger rhetorical conviction and minimal caveats.

Logical Coherence

Internal Structure

- Well-organized chapters with clear progression:
 - From systemic critique (e.g., peer review process, overconfidence) to granular examples (e.g., precipitation trends, heatwave framing).
 - Inclusion of references, appendices, and traceability comments reinforces formal review tone.

Coherence Gaps

- **Circular referencing:** The report repeatedly relies on CWG25 to corroborate its claims, creating a loop rather than triangulating with independent peer-reviewed sources.
- **Generalizations from anecdotes:** Statements about young scientists “trying to save the planet” or critiques of NCA5’s cover image veer into editorial territory and dilute the analytical focus.
- **Recommendations blend science and policy ideology:** Calls to rewrite the Global Change Research Act or eliminate regional climate projections are rooted more in philosophical disagreement than scientific infeasibility.

Summary Judgment

Dimension	Verdict
Scientific Accuracy	Substantive methodological critiques, selective evidence base
Tone	Adversarial and rhetorically charged
Bias and Framing	Heavy reliance on contrarian sources; limited engagement with consensus science
Logical Coherence	Structured and readable, but occasionally editorial and circular

This is a technically informed but ideologically framed critique. It raises valid concerns about uncertainty treatment, scenario realism, and statistical rigor in NCA5—but it's shaped by a strong counter-narrative lens. Its scientific merit would be strengthened by more diverse sourcing, clearer separation of analysis and editorialism, and a broader epistemic perspective.

From: Judith Curry <curry.judith@gmail.com>
Sent: Sunday, July 13, 2025 3:12 PM
To: Ross McKittrick <ross.mckittrick@gmail.com>
Cc: Steven Koonin <steven.koonin@gmail.com>; John Christy <climateman60@gmail.com>; Roy W. Spencer <roywspencer@hotmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>; Josh Loucks <loucksj14@gmail.com>; Seth Cohen <seth.cohen@hq.doe.gov>
Subject: Re: NCA5 progress

see attached for a shorter, desmarked version of NCA5 for you to consider. I didn't do track changes, its clean text

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On Sat, Jul 12, 2025 at 6:18 PM Steven Koonin <steven.koonin@gmail.com> wrote:

Ross- Can you send around the most recent version of the NCA5 review. I can't seem to identify it in the emails and would like to go through it again in the next few days.

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John C.

Sent from my iPhone

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On Jul 11, 2025, at 10:07 AM, John Christy <climateman60@gmail.com> wrote:

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... Christy, McKittrick and Koonin ... you could look at it this way: we're the only ones willing to stick our heads up when the bullets are flying and endure protracted battles with editors and reviewers. Publishing in journals in this "climate" takes its toll, and most folks with an objective side just give up. We would love to cite other authors who do these NCA5-type analyses using the proper methods ... there just aren't many out there. As you know, there's no profit (or funding) in fighting the climate establishment. However, please, let us know if you see something we've missed.

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On Fri, Jul 11, 2025 at 11:21 AM Judith Curry <curry.judith@gmail.com> wrote:

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What i'm struggling with in the NCA5 critique is that if you read it without an author list, you would figure the authors are christy, mckitrick, koonin. This should be a relatively short, high-level critique and IMO we need to depersonalize this

On Fri, Jul 11, 2025 at 8:19 AM Ross McKitrick <ross.mckitrick@gmail.com> wrote:

We seem to have stalled on iterating the NCA5 report. Here are the issues on the table:

1. Whether to drop Section 1.4

- my thinking is I like the idea of the section because it justifies why we would presume to critique a report that has already gone through 11 government agencies and a National Academies review. At the same time I think it could be shortened and made more effective with a different version of the Figure from CWG25. John if you can you send me the spreadsheet you used I'll propose a rewrite.

2. Do we include a case study of the Texas floods?

- What I like about that section is that it is a vivid example of how a document that could have provided useful info for disaster planners not only failed to do so, but it would have misdirected resources if they were to have relied on it. But it's easy to have 20/20 hindsight. Presumably somewhere in the US at this moment there are several potential weather-related hazards poised to cause death and destruction later this year, and the local authorities are not ready for them. We need to explain what it would look like for an NCA to be a useful resource in that context. What say ye all?

3. Tidying

- I find the LLM critiques to be somewhat helpful in anticipating possible lines of attack, but they are overly algorithmic and often end up saying "they make a valid point but that's not the consensus so it's probably wrong." And it seems to have hallucinated about things we didn't even say. Still, it points to the need to guard against snark.

--

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From: Travis Fisher <travis.scott.fisher@gmail.com>
Sent: Tuesday, July 15, 2025 1:47 PM
To: Steven Koonin
Cc: Judith Curry; Ross McKittrick; John Christy; Roy W. Spencer; Josh Loucks; Seth Cohen
Subject: Re: NCA5 progress

Hi all,

If we need to move quickly to publish the NCA critique as a DOE product, what would be a reasonable date for us to consider it final from the authors' point of view (subject to internal review for errors but not subject to political meddling)? I have to build a publication schedule, and I'd like to work backward from a date that's comfortable for you all.

I ask because the political powers that be are interested in having a published version to cite. Sooner is better, of course, but I don't want to jam you up. They certainly want it to be published before we could conceivably have a new head of the USGCRP, so it will have to be a DOE report.

Finally, if you're considering critiquing the entire NCA apparatus and previous reports, I think that would be helpful. The political response to an NCA5 critique so far has been (I'm paraphrasing), "Even if we show that NCA5 is not a solid basis for policymaking, what about NCA4 and prior reports?"

As always, please feel free to call me or convene a meeting if you want to discuss anything. I'll also try to keep everyone posted as the CWG report moves through the necessary hoops.

Best,
Travis

On Tue, Jul 15, 2025 at 11:41 AM Steven Koonin <steven.koonin@gmail.com> wrote:

I've marked up Judy's "desnarked" version (attached). Mostly typos and wording, but a few issues of substance. And still on the fence about whether and how to include the NCA4 story on temperature extremes.

SEK

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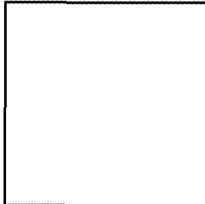
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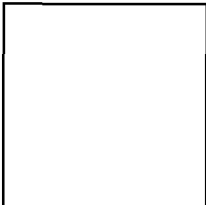
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Sent: 7/15/2025 6:07:01 PM
To: Travis Fisher [travis.scott.fisher@gmail.com]; Steven Koonin [steven.koonin@gmail.com]
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Subject: Re: NCA5 progress

Now that's a conundrum I would have never thought of:

"Even if we show that NCA5 is not a solid basis for policymaking, what about NCA4 and prior reports?"

If the most recent science assessment isn't assumed to be the best, how far back do we go? To before global warming was a thing? This would set quite a precedent...

"OK, maybe the latest IPCC report has some problems... but what about the first one?"

Ugh.

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Sent: Tuesday, July 15, 2025 12:46 PM
To: Steven Koonin <steven.koonin@gmail.com>
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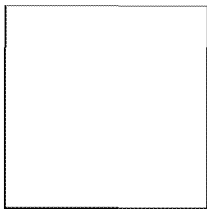
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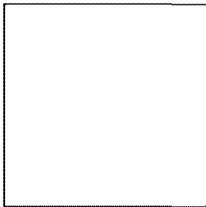
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Cc: Ross McKittrick; Steven Koonin; John Christy; Roy W. Spencer; Josh Loucks; Seth Cohen
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It was just an idea based on some of the political back-and-forth I've seen take place recently. I agree it gets us into the weird position of having to refute every govt report on climate change. Not great. I also don't want to add new work just as we're trying to wrap it up.

On Tue, Jul 15, 2025 at 2:32 PM Judith Curry <curry.judith@gmail.com> wrote:

What can we say about NCA4 that is more substantive than section 1.4? It still had the same problems with extreme scenarios, overconfidence etc. We should include such a statement in ch 8, stating that apart from the activist tone, the previous NCA reports had the same problem. Specifically with regards to NCA4 Vol 1, IMO that was a cut below the IPCC AR4 and much of that is significantly outdated.

On Tue, Jul 15, 2025 at 11:03 AM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

Could have it in by the end of the week.

From Travis' comment our earlier material on the failure of nca4 peer review should stay in

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We might be close on the NCA5 report. Ross, an estimate?

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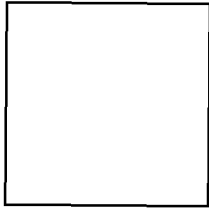
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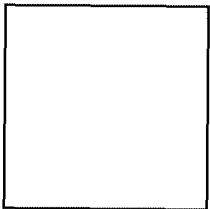
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Subject: Re: NCA5 progress

A couple of my folks did a quick write up of the TX floods.

<https://www.earthdata.nasa.gov/dashboard/stories/tx-flood>

John C.

On Fri, Jul 18, 2025 at 9:22 AM Judith Curry <curry.judith@gmail.com> wrote:
Thoughts on turning section 8.4 into a separate chapter, e.g.

8. Regional example: Texas 2025 floods

9. Conclusions and recommendations for NCA6

On Fri, Jul 18, 2025 at 3:28 AM Roy Spencer <roywspencer@hotmail.com> wrote:
I've added several edits to Judy's version (attached).

-Roy

From: Steven Koonin <steven.koonin@gmail.com>
Sent: Wednesday, July 16, 2025 5:29 AM
To: 'Judith Curry' <curry.judith@gmail.com>; 'Ross McKittrick' <ross.mckittrick@gmail.com>
Cc: 'John Christy' <climateman60@gmail.com>; 'Travis Fisher' <travis.scott.fisher@gmail.com>; 'Roy W. Spencer' <roywspencer@hotmail.com>; 'Josh Loucks' <loucksj14@gmail.com>; 'Seth Cohen' <seth.cohen@hq.doe.gov>
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And my further edits attached.

Do keep me at least cc'd over the next few days – I'll respond as I'm able.

SEK

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Here is my revised version. One proposed change of substance, relates to TX floods.

In section 8.3, i proposed modifying one of the bullets:

- The range of climatic and weather conditions, including extremes, that have occurred in the past and can reasonably be expected to occur in U.S. regions over the near future. An example of a salient acute failure is the NCA5 chapter (region that includes Texas) that fails to mention the historical occurrence and future risk of flash floods in the Texas Hill Country ROSS MAYBE MENTION WHAT NCA5 SAID ABOUT TX FLOODS in REGIONAL CHAPTER, THEN INCLUDE LINK TO YOUR MINI ANALYSIS

An alternative approach would be to add a new chapter on Failure to document the risk of extreme events based on the historical data base, something like that. Simpler just to mention it in Section 8.3

On Tue, Jul 15, 2025 at 3:33 PM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

If Steve's away until Tuesday a Friday July 18 deadline won't be feasible, so let's work towards a Friday July 25 deadline.

I propose this week we go in the following order to prevent us working on overlapping drafts

Judy goes through the draft tonight

Steve has another look tomorrow.

Then Roy, then John, then me.

On Tue, Jul 15, 2025 at 3:47 PM John Christy <climateman60@gmail.com> wrote:

I like Judy's idea. It's one way to avoid going through the preparation and experience of something like a colonoscopy twice in one month.

John C.

On Tue, Jul 15, 2025 at 2:12 PM Judith Curry <curry.judith@gmail.com> wrote:

Here is a way around the NCA4 issue, propose adding the following text to end of section 8.3

NCA4 provided a better assessment than NCA5 in terms of a more thorough consideration climate science, use of data back to 1901, and less of an advocacy tone. However, NCA4 shared the following endemic problems with NCA5

- Overconfidence in conclusions
- Inadequate treatment of natural variability
- Inadequate Traceable Accounts and communication of uncertainty
- Over reliance on extreme scenarios

On Tue, Jul 15, 2025 at 12:02 PM Steven Koonin <steven.koonin@gmail.com> wrote:

Just a heads up that I will be on the West Coast with very limited connectivity from tomorrow (Wednesday) evening through Monday evening (West Coast times). Back on the East Coast early Tuesday morning.

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From: Ross McKittrick <ross.mckittrick@gmail.com>

Sent: Friday, July 11, 2025 3:49 PM

To: John Christy <climatemanager60@gmail.com>

Cc: judith curry <curry.judith@gmail.com>; Roy W. Spencer <roywspencer@hotmail.com>; Steven Koonin <steven.koonin@gmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>; Josh Loucks <loucksj14@gmail.com>; Seth Cohen <seth.cohen@hq.doe.gov>

Subject: Re: NCA5 progress

John and I only appear in Section 4.1 as part of challenging the reproducibility of the NCA5 Key Message regarding precipitation. 2 of our 3 citations in the reference list are data archives which are there for transparency purposes.

On Fri, Jul 11, 2025 at 2:53 PM John Christy <climatemanager60@gmail.com> wrote:

Judy

I must be missing something. Our papers directly address the issues espoused by NCA5. We offer all the data and methods. Why should our work be suppressed?

John C.

Sent from my iPhone

On Jul 11, 2025, at 1:16 PM, judith curry <curry.judith@gmail.com> wrote:

We need to think about our audience who we want to reach and influence. We don't want this to be another salvo in the climate wars. But to rise above it and be hyper objective.

Sent from my iPhone

On Jul 11, 2025, at 10:07 AM, John Christy <climateman60@gmail.com> wrote:

Judy

... Christy, McKittrick and Koonin ... you could look at it this way: we're the only ones willing to stick our heads up when the bullets are flying and endure protracted battles with editors and reviewers. Publishing in journals in this "climate" takes its toll, and most folks with an objective side just give up. We would love to cite other authors who do these NCA5-type analyses using the proper methods ... there just aren't many out there. As you know, there's no profit (or funding) in fighting the climate establishment. However, please, let us know if you see something we've missed.

John C.

On Fri, Jul 11, 2025 at 11:21 AM Judith Curry <curry.judith@gmail.com> wrote:

Re 1.4 and TX, i suggest we incorporate these points briefly in existing chapters. The content of 1.4 is already covered in CWG, apart from the convoluted peer review issue. CWG adequately covers temperature extremes, we don't need more of that in NCA beyond length of temperature records. Re TX, might fit best in CWG attribution, but its too early for that I think.

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On Fri, Jul 11, 2025 at 8:19 AM Ross McKittrick <ross.mckitrick@gmail.com> wrote:

We seem to have stalled on iterating the NCA5 report. Here are the issues on the table:

1. Whether to drop Section 1.4

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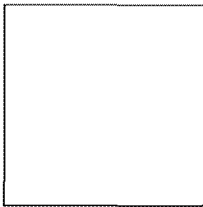
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3. Tidying

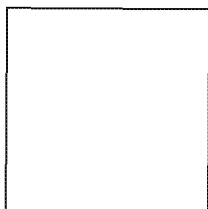
- I find the LLM critiques to be somewhat helpful in anticipating possible lines of attack, but they are overly algorithmic and often end up saying "they make a valid point but that's not the consensus so it's probably wrong." And it seems to have hallucinated about things we didn't even say. Still, it points to the need to guard against snark.

--



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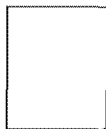
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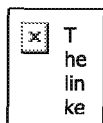
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From: Judith Curry <curry.judith@gmail.com>
Sent: Friday, July 11, 2025 12:22 PM
To: Ross McKittrick
Cc: Roy W. Spencer; John Christy; Steven Koonin; Travis Fisher; Josh Loucks; Cohen, Seth
Subject: Re: NCA5 progress

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From: Ross McKittrick <ross.mckittrick@gmail.com>
Sent: Wednesday, June 18, 2025 11:38 AM
To: Judith Curry
Cc: John Christy; Steven Koonin; Roy W. Spencer; Travis Fisher; Josh Loucks
Subject: Re: NCA5 report, June 17 edition

Upon several re-readings (which I'm just about done) I would make the case for Appendix 3 by framing it as a test of whether Key Message 2.2 is reproducible, particularly the elaboration

"Rainfall is becoming more extreme: Since the 1950s, there has been an upward trend in heavy precipitation **across the contiguous US**. This increase is driven largely by more frequent precipitation extremes, with relatively smaller changes in their intensity."

As part of our due diligence we are addressing reproducibility. We've taken a large group of USHCN precip records and showed not only that the trends aren't robust to the chosen sample length, but that even for the post-1950 sample we can't reproduce this finding across regions. I'm adding in a bit of language to set this context.

On Wed, Jun 18, 2025 at 10:57 AM Judith Curry <curry.judith@gmail.com> wrote:

John I guess the point I'm making hinges on whether this doc is a scientific review of NCA5, or an assessment of NCA5's fitness for purpose to advise US policy making. Obviously these are not completely independent, but the difference does speak to the level of attention that we pay to individual graphs, etc.

On Tue, Jun 17, 2025 at 6:42 PM John Christy <climateman60@gmail.com> wrote:

Judy

If we are evaluating NCA5 can't we do so by directly checking their claims as reviewers with expertise in these areas? I'm referring to the extreme precip claims on which we have published and are qualified to be expert reviewers (and in truth provide analyses that are more accurate).

John C.

Sent from my iPhone

On Jun 17, 2025, at 2:46 PM, Judith Curry <curry.judith@gmail.com> wrote:

Some good stuff added by SK. My edits are attached.

My more substantive comments:

Delete Chapter 7 NASEM Review (this is pretty weak, and looks like it needs alot more work)

Completely rewrite Chapter 8 Summary

Delete Appendix 3 (we should not be showing any original analyses in this report)

On Tue, Jun 17, 2025 at 2:26 PM Steven Koonin <steven.koonin@gmail.com> wrote:

The attached accepted all the changes in Ross' June 13 version and then tracked subsequent changes.

I've done a close edit of the entire text and added an executive summary and concluding chapter. I also worked on the NASEM review chapter, but there's still a bit missing.

As you'll see, a few other bits are still missing, but this should serve as a basis for our discussion on Friday.

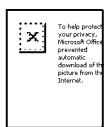
SEK

From: Ross McKittrick <ross.mckittrick@gmail.com>
Sent: Friday, June 13, 2025 8:44 AM
To: Judith Curry <curry.judith@gmail.com>; Roy W. Spencer <roywspencer@hotmail.com>; John Christy <climateman60@gmail.com>; Steven Koonin <steven.koonin@googlemail.com>; Travis Fisher <travis.scott.fisher@gmail.com>; Josh Loucks <loucksj14@gmail.com>
Subject: June 13 edition - for SEK review

This is the current version for Steve to go through. I've added NASEM review material in Ch 7 currently as a placeholder and we'll work on that stuff offline.

Ross

--



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<01.NCA5.Review.June17 [SEK] Curry.docx>

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To help protect
your privacy,
Microsoft Office
prevented
automatic
download of this
picture from the
Internet.

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From: Judith Curry [curry.judith@gmail.com]
Sent: 6/17/2025 10:46:21 PM
To: Steven Koonin [steven.koonin@gmail.com]
CC: Ross McKittrick [ross.mckittrick@gmail.com]; Roy W. Spencer [roywspencer@hotmail.com]; John Christy [climatemanager60@gmail.com]; Travis Fisher [travis.scott.fisher@gmail.com]; Josh Loucks [loucksj14@gmail.com]
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Attachments: 01.NCA5.Review.June17 [SEK] Curry.docx

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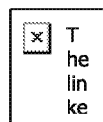
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Review of the Fifth National Climate Assessment

EXECUTIVE SUMMARY	3
1 INTRODUCTION	4
1.1 ABOUT THIS REPORT	4
1.2 ABOUT THE NATIONAL CLIMATE ASSESSMENTS	4
1.3 STANDARDS FOR ASSESSING NCA PRODUCTS	5
1.4 WHEN PEER REVIEW FAILS	7
2 NCA5 OVERVIEW CHAPTER: HYPERBOLIC ADVOCACY LANGUAGE AND UNSCIENTIFIC TONE.....	11
3 OVERCONFIDENCE WHEN STATING CONCLUSIONS	13
3.1 INFLATED CERTAINTY LEVELS	13
3.2 OVERSTATING FINDINGS IN UNDERLYING SOURCES	14
3.3 TECHNICAL EXAMPLE: EMERGENT CONSTRAINTS	16
4 RELIANCE ON <i>AD HOC</i> TIME SCALES FOR TREND ANALYSIS	18
4.1 AVERAGE AND EXTREME PRECIPITATION.....	18
4.2 HEATWAVES.....	19
5 INADEQUATE TRACEABLE ACCOUNTS.....	22
6 OVEREMPHASIS ON EXTREME SCENARIOS	24
7 INADEQUATE NASEM REVIEW: TO BE ADDED.....	26
7.1 SUBSTANTIVE CRITICISMS BY NASEM.....	26
7.2 FAILURES TO CHALLENGE NCA5 FLAWS.....	26
8 SUMMARY EVALUATION OF NCA5	28
APPENDICES.....	28
APPENDIX 1: CHARGE TO THE REVIEW	28
APPENDIX 2: STATUTORY REQUIREMENTS FOR NCA5	28
APPENDIX 3: ANALYSIS OF U.S. LONGTERM PRECIPITATION RECORDS	29
ABOUT THE AUTHORS.....	38

EXECUTIVE SUMMARY

This report critically evaluates the Fifth National Climate Assessment (NCA5), finding it an inadequate basis for climate and energy policies. A detailed review of the foundational chapters on climate science raises several key concerns:

Scientific Integrity

- An advocacy tone, particularly in the Overview chapter, inconsistent with scientific objectivity
- An endemic overconfidence when stating conclusions, including inflated certainty levels and overstatement of findings from underlying sources

Flawed methodology

- Use of *ad hoc* time scales for trend analyses in areas such as precipitation and heatwaves
- An overemphasis on extreme scenarios for future emissions
- Inadequate traceable accounts to support key conclusions

Deficient Review Process

- A review by the National Academy of Sciences, Engineering, and Medicine (NASEM) failed to challenge some fundamental flaws in NCA5
- The NCA5 authors failed to adopt some improvements recommended by NASEM

The report shows NCA5 to be a biased and incomplete picture of climate science that skews toward excessive climate risk. Consequently, NCA5 should not be used as basis for climate and energy policies.

1 INTRODUCTION

1.1 About this Report

This report responds to a request from OSTP Director Michael Kratsios (reproduced in Appendix1) that we assess the suitability of the Fifth National Climate Assessment for informing climate and energy policies.

To conduct this assessment we reviewed NCA5 itself, the National Academies (NASEM) review of the Third Order Draft, and the USGCRP responses to that review. We have drawn upon our long experience working on advisory reports, including for the NASEM, the IPCC and other organizations, as writers, reviewers and study leaders.

We find that NCA5 should not be relied on for policy making as it is an incomplete and misleading picture of our understanding of the changing climate and the risks it poses to the nation. NCA5 was selective and incomplete in its survey of climate science as of its publication in 2023 and has become even more so in the years since. We have reviewed many key scientific developments in a separate report to Energy Secretary Wright (Climate Working Group 2025, herein denoted “CWG25”). The overall effect of the biases and omissions of NCA5 is an excessively dire picture of climate risk.

To support our finding, the following sections of this chapter provide some background on the National Climate Assessments and the standards by which we have assessed NCA5. Chapters 2 through 6 then detail important ways in which NCA5 fails to meet those standards. In Chapter 7, then follows with an assessment of the NASEM review. Finally, Chapter 8 summarizes our evaluation of NCA5.

1.2 About the National Climate Assessments

The U.S. Global Change Research Program (USGCRP) was established by Presidential Initiative in 1989 and mandated by Congress in the Global Change Research Act (GCRA) of 1990 to develop and coordinate “a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change.”

The National Climate Assessment (NCA) Reports evolved from the GCRA requirement to

Prepare and submit to the President and the Congress an assessment which (1) integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings; (2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and (3) analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

The five NCA Reports to date have interpreted this mandate in different ways:

- NCA1 (2000) was a multidisciplinary effort to study and portray in regional detail the potential effects of human-induced global warming on the United States.
- NCA2 (2009) was a relatively short report that not only focused on the potential consequences of climate change but also sought to identify potential adaptation measures and identify the highest priorities for future research.

- NCA3 (2014) was an expanded effort that continued along the lines of NCA2, and was distinguished by a comprehensive review process, including a review by the National Academy of Sciences. NCA3 introduced a traceability analysis for each key finding, including a description of uncertainties.
- NCA4 (2017/2018) was a further expanded effort published in two volumes: I Climate Science Special Report, and II Impacts, Risk, and Adaptation in the United States. This was the first NCA report to devote significant effort to assessing climate science.
- NCA5 (2023) returned to a single volume format, reducing discussion of climate science to a cursory two chapters, with continuing with a focus on regional and sectoral impacts of climate change. NCA5 expanded its remit to topics that are arguably outside the purview of the USGCRP, focusing on “Climate Action” and policy recommendations with a social justice emphasis. NCA5’s self-description is reproduced as Appendix II.

These successive interpretations of the NCA are poorly aligned with the GCRA’s statutory requirements. Only NCA4 gives serious consideration to climate science, which receives the great majority of USGCRP funding, and even then misrepresents some important points (Section 1.4 below offers an example). Natural climate variability is essentially dismissed as unimportant in NCA4 and barely mentioned in NCA5 in most contexts, despite the mandate to include both human-caused and natural climate change. Most significantly, NCA5 has redirected the focus away from climate science and even the hazard elements of impacts, towards evaluation of societal vulnerabilities and advocacy for particular policy options, especially wind and solar power. The cover image for the NCA5 Report is the installation of a solar panel.

1.3 Standards for Assessing NCA Products

In Appendix 2 we include a letter of guidance from the Office of General Counsel, U.S. Department of Energy, summarizing the statutory requirements governing USGCRP work products in general and NCA products in particular.

We can summarize the standards applicable to the NCA as follows:

- details

Beyond the statutory requirements we draw attention to two other pertinent standards. President Trump’s executive order of May 23, 2025, “Restoring Gold Standard Science” enumerates some of the characteristics of good science:

- i. reproducible;
- ii. transparent;
- iii. communicative of error and uncertainty;
- iv. collaborative and interdisciplinary;
- v. skeptical of its findings and assumptions;
- vi. structured for falsifiability of hypotheses;
- vii. subject to unbiased peer review;
- viii. accepting of negative results as positive outcomes; and
- ix. without conflicts of interest.

Although these should be self-evident to those trained in science, it is surprising that some scientists have found them controversial.

There are other desiderata for scientific reports that will be highly influential on climate policymaking. Among them are statements about the strength of climate knowledge. The IPCC's approach is based on judgment of the available evidence and agreement among experts. More sophisticated knowledge characterizations for risk management include (Aven 2017)¹:

- The degree to which the assumptions made are reasonable/realistic based on background knowledge
- The degree to which data/information exists and are reliable and relevant
- The degree to which there is disagreement among experts (including those from different environments or academic fields)
- The degree to which the phenomena involved are understood and accurate models exist
- The degree to which the knowledge has been thoroughly examined with respect to unknown knowns

Good climate and energy policies will balance the risks and benefits of a changing climate against the world's growing demand for reliable and affordable energy. To strike that balance, policymakers must understand at least two complex and nuanced topics: the certainties and uncertainties of climate science and the technoeconomic realities of energy systems. Experts in those subjects have a unique responsibility to communicate their understanding to non-experts clearly, completely, and without bias.

Expertise in energy systems resides largely in the private sector, where it is essential to providing the reliable and affordable energy services that are the lifeblood of society. Understanding is therefore continually refined and tested by the discipline of the marketplace. In contrast, climate science expertise is found largely in the non-profit realm of universities and government laboratories and so has a more academic character.

In recent decades, climate science has engendered passion and emotion. Indeed, some younger climate scientists have gone into the field to "save the planet." Further, the field of climate science has been politicized by NetZero mandates. It is then not surprising that objectivity can suffer when climate scientists communicate their understanding to non-experts. This lack of objectivity usurps the public's right to make informed choices and undermines their confidence in the scientific enterprise.

In 1980, then-President of the National Academy of Sciences Philip Handler identified the problem in an editorial² that resonates eerily four decades later:

Difficulty arises in the scientific community from confusion of the role of scientist *qua* scientist with that of scientist as citizen, confusion of the ethical code of the scientist with the obligation of the citizen, blurring the distinction between intrinsically scientific and intrinsically political questions. When scientists fail to recognize these boundaries, their own ideological beliefs, usually unspoken, easily becloud seemingly scientific debate.

¹ Aven, Terje (2017) "Improving Risk Characterisations in Practical Situations by Highlighting Knowledge Aspects, with Applications to Risk Matrices," *Reliability Engineering & System Safety* 167 (November 2017): 42–48 <https://www.sciencedirect.com/science/article/pii/S0951832016306950>

² Handler, Philip (1980) Public Doubts About Science. *Science* 208(4448) p. 1093 <https://www.science.org/doi/10.1126/science.208.4448.1093>

1.4 When Peer Review Fails

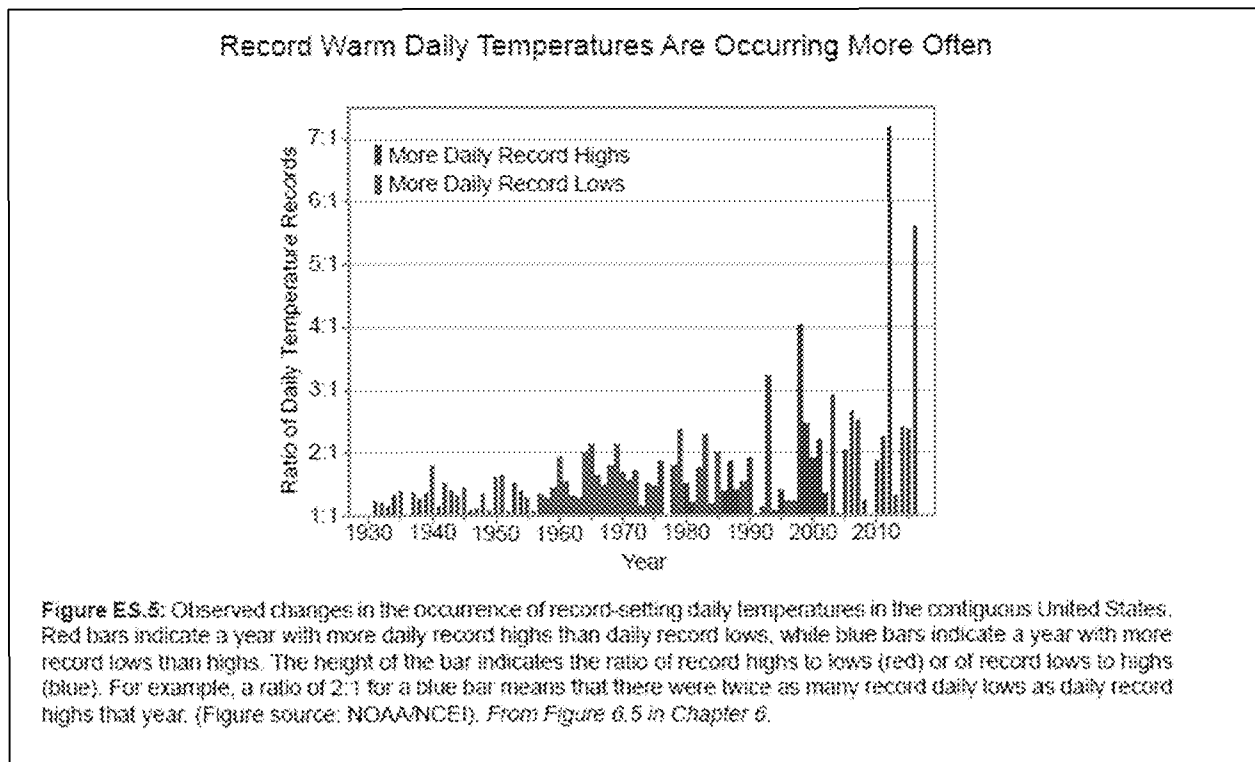
Peer review of reports like IPCC and NCA products is not a silver bullet that guarantees quality. The peer review process for these reports differs in some important respects from traditional peer review in academic journals. First, NCA reviewers are volunteers who self-select what parts of the report to read, whereas the editors of academic journals recruit reviewers and assign them to specific papers. As a result, there is no guarantee that any particular section of an NCA report was reviewed by anyone, **WHAT ABOUT THE NASEM REVIEW?** let alone by someone with a perspective that differs from the authors. In fact, many potential reviewers have given up over the years because their input has systematically been ignored. Second, NCA authors have near complete authority whether to accept or reject review comments. By contrast, the Editor of an academic journal mandates the author to respond and the reviewer and editor ~~gets to~~ assess its adequacy. And third, the work of an NCA chapter author team is guaranteed to be published, whereas academic journals routinely reject papers that do not pass review.

These points are important to bear in mind because some readers might dismiss any criticism of NCA products out of hand on the grounds that they were “peer reviewed”. But the test of a report is whether its contents are a valid representation of the available evidence. Here we give an example in which NCA4 gave prominence to a figure that completely misrepresented the underlying data and which evaded peer review to do so. Further details can be found in Koonin (2024).

As shown in CWG25 Section 6.3 the number of heat extremes in the U.S. peaked in the 1930s and has declined ever since. Considering cold and hot extremes together the U.S. the U.S. climate has become more moderate over time. NCA4’s Part I (Climate Science Special Report, CCSR) says (prominently and with *Very High Confidence*) on Page 19 of the Executive Summary:

There have been marked changes in temperature extremes across the contiguous United States. The number of high temperature records set in the past two decades far exceeds the number of low temperature records.

and offers this figure in support:

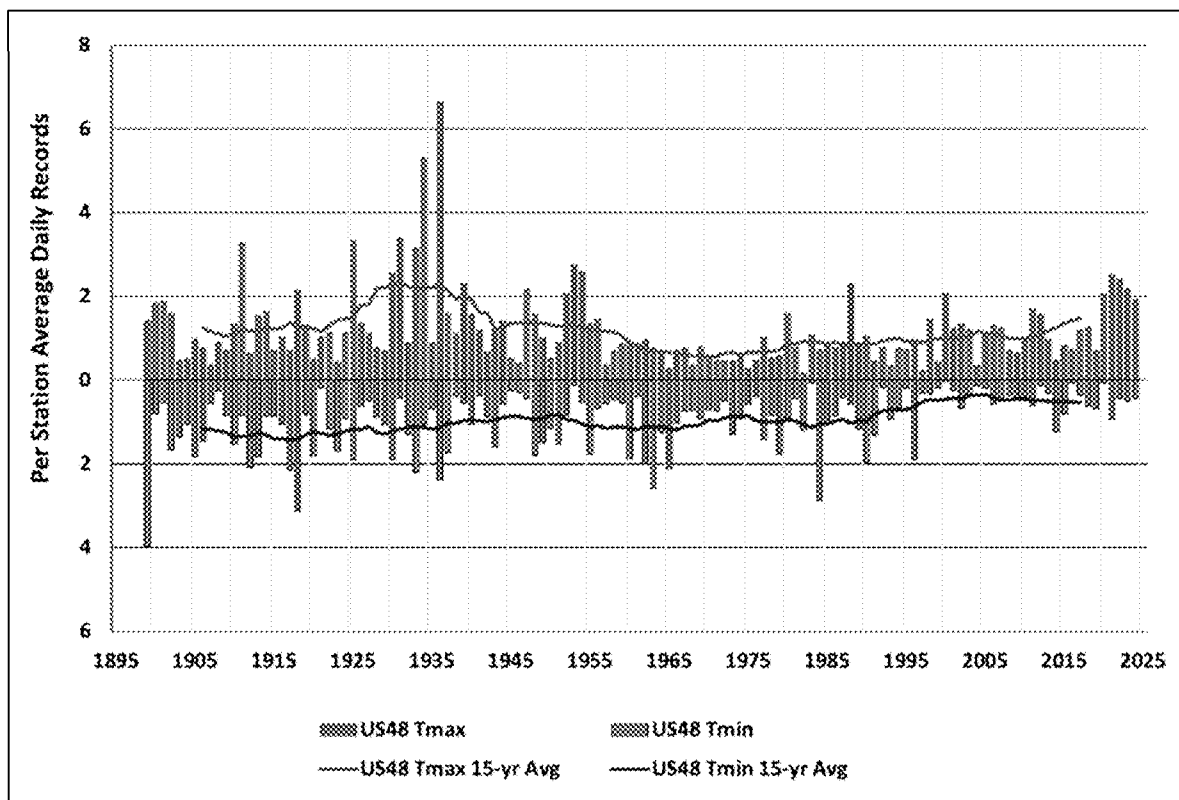


The figure appears to validate the claim that record warm daily temperatures are occurring more often. But the underlying data do not. Rather, they show that extreme heat in the U.S. peaked in the 1920s and 1930s and declined thereafter, as supported by Figure 6.4 deep within the CSSR itself (reproduced in our Section 4.2 below).

Figure ES.5 does not even show what its title implies, as it displays not simple counts of cold and warm extreme events, but rather ratios of the two counts. In fact, both types of extremes declined over the sample interval, but cold events declined more than warm events, so the ratio of warm extremes to cold extremes increased. By graphing the ratio instead of counts, NCA4 creates a visual impression opposite to what is in the data.

Figure 6.3.3 of CWG25 (reproduced below) shows the results of a proper analysis of the data – defining each record as the singular extreme in the sample interval, displaying numbers of warm and cold records separately, and beginning the analysis in 1899 rather than 1930. It makes evident the exceptional heat of the 1920s and especially the 1930s, peaking in 1936.³ The frequency of cold records has declined, especially over the last quarter of the period in which only 13 percent of the extreme cold events were measured. In contrast, 25 percent of the heat records were achieved in the last quarter, which is consistent with statistical expectations. As a result, the ratio of heat to cold extremes shown in Figure ES.5 of the CSSR explodes in recent decades. The overall reduction in numbers of both cold and hot extremes over the past century indicates a climate *less* prone to extremes, in sharp contrast to the message of NCA4 Figure ES.5.

³ The increased heat of the past five years is too brief to be deemed climatically significant and, in any event, occurred after the CSSR was published in 2017.



Number of daily record High (red) and Low (blue) temperatures for warm and cold seasons in the CONUS. The lines represent the 15-year running, centered average. Source: 1,211 USHCN stations supplemented as needed to achieve a minimum of 92 percent of observations in the 126-year period since Dec 1898. US48: contiguous U.S. states. Tmax: maximum temperature. Tmin: minimum temperature. Source: CWG25 Figure 6.3.3.

The National Academies' expert review panel criticized the discussion of temperature extremes in a late draft of the CSSR. In reference to the CSSR's Key Finding 2 of Chapter 6, they said:

Further, it is difficult to understand how a statement that includes increases in extreme warmth can be associated with a high confidence or extremely likely statement, given that most of the graphics in this chapter show a decrease in extreme warmth in the historical record.

The Federal official in charge of the CSSR (Michael Kuperberg, Executive Director of the USGCRP) responded to the Academies' review by noting that

Almost every recommendation from the NAS was incorporated [in the final version]... and a new figure was added on changes in record high and low temperatures

The "new figure" referred to is the Figure ES.5, which did not appear in the draft reviewed by the Academies' panel. It seems unlikely that the Academies panel ever saw that figure because they

surely would have commented if they had and it wouldn't have survived to publication. And the figure's problems were evidently not flagged (or were ignored) in the subsequent internal government reviews.

With this background we now present our critique of NCA5.

2 NCA5 OVERVIEW CHAPTER: HYPERBOLIC ADVOCACY LANGUAGE AND UNSCIENTIFIC TONE

[Fix formatting in "UNSCIENTIFIC"]

NCA5 Chapter 1, "Overview", holds a prominent place in the Report since it summarizes the entire whole report and is the only section that many will read. Although the later chapters of NCA5 contain much sound scholarly content, Chapter 1 is marred by an activist tone and language that aggressively promotes mitigation policies. As such, this chapter adds an imprimatur of scientific authority to oversimplified declarations of opinion about public policy. Many examples can be cited; here we note a few that are particularly egregious.

Chapter 1 opens as follows:

The more the planet warms, the greater the impacts. Without rapid and deep reductions in global greenhouse gas emissions from human activities, the risks of accelerating sea level rise, intensifying extreme weather, and other harmful climate impacts will continue to grow. Each additional increment of warming is expected to lead to more damage and greater economic losses compared to previous increments of warming, while the risk of catastrophic or unforeseen consequences also increases.

This statement presupposes that all warming is anthropogenic, that all warming is bad and causes economic damage, and that warming intensifies extreme weather. Such sweeping generalizations go well beyond what science has or can establish. The statement also refers to growing risks without saying whether they were large to begin with -- a small risk that grows may still be a small risk, and a large risk may be only incrementally worsened. A scientifically-sound version of this paragraph would instead say something like the following:

The Earth is warming because of a combination of natural and anthropogenic influences. This warming will generate a mix of benefits and harms that varies by region, to which society should be prepared to adapt. Some types of extreme weather have worsened recently, while others have not changed or have even declined in intensity. Reducing emissions of greenhouse gases might slow the warming although such policies have proven to be costly and disruptive, so any climate actions to be weighed against the potential benefits.

On the next page the Overview states ~~goes on to say~~:

Each additional increment of warming leads to greater risks [here it lists 7 key components of society including food security and the economy]... Without deeper cuts in global net emissions, climate risks to the US will continue to grow... Action to limit future warming and reduce risks can have near-term benefits and opportunities: low-carbon energy jobs, Improved air quality, Health benefits, Economic benefits..."

The authors write as if climate policy does not involve trade-offs and all measures to reduce future warming will be effective and beneficial. But the vast body of scholarship on climate science and economics does not support such simplistic claims. Not every additional increment of warming leads to economic harms; in fact, NCA5 Chapter 19 acknowledges that there will also be benefits. Nor is

climate policy guaranteed to create jobs or benefit the economy; in many cases it has done the opposite. Such deceit is a disservice to policymakers.

Pages 8 and 9 of the Overview promote renewable energy options by noting, correctly, that the leveled costs of wind/solar generation have fallen sharply since 2010, and so offers this rationale for pursuing deep emission reductions:

Recent growth in the capacities of wind, solar, and battery storage technologies is supported by rapidly falling costs of zero- and low-carbon energy technologies, which can support even deeper emissions reductions. For example, wind and solar energy costs dropped 70% and 90%, respectively, over the last decade, while 80% of new generation capacity in 2020 came from renewable sources.

Yet it has long been known that intermittent renewables generation must be supplemented by dispatchable generation to meet grid reliability standards, and that doing so (e.g., through natural gas, fission, or storage) significantly increases the cost of electricity. Further, there are yet unmet synchronization challenges in transmission grids with heavy penetration of wind and solar power. Here again it is advisory malpractice not to acknowledge these facts.

Page 14 of the Overview presents future emission scenarios with the following description: “Climate modeling experts develop global climate projections for a range of plausible futures.” The word “plausible” is applied to all of the scenarios. The accompanying Figure includes both SSP3-7.0 and SSP5-8.5, the latter reaching the same radiative forcing as RCP8.5. The Figure does not compare observed emissions with previous projections nor does it caution readers that SSP3-7.0 and SSP5-8.5 are extreme worst case scenarios that, like RCP8.5, have been heavily criticized in the scientific literature (CWG25 3.2.1). By describing the entire envelope of emission projections as “plausible” the report opens the door to later presenting impacts associated with extreme and implausible emission scenarios as part of a baseline “business-as-usual” future.

Page 17 of the Overview introduces the discussion of risks from extreme weather events by saying “Harmful impacts from more frequent and severe extremes are increasing across the country.” This creates the impression that disaster losses are driven by trends in extreme weather. While the section goes on to acknowledge that some of the increase is due to increases in the value of assets at risk it then invokes the NOAA Billion Dollar Dataset as evidence of extreme weather getting worse. Scientists have shown that this is an invalid metric (CWG 10.2) since it measures the growth of the economy not the frequency of extreme weather, and indeed NOAA has recently withdrawn the data product. REFERENCE PIELKE JR PAPER Even though it was still distributed by NOAA at the time of the NCA5, the report authors should have assessed it skeptically and seen that it was unfit for the purpose of measuring climate trends.

Page 23 of the Overview states, in large font:

Climate changes are making it harder to maintain safe homes and healthy families; reliable public services; a sustainable economy; thriving ecosystems, cultures, and traditions; and strong communities.

It is pointless to try to evaluate this statement on scholarly grounds; it is self-evidently hyperbolic. This kind of language doesn’t belong in a scientific assessment report. Its prominent inclusion points not only to the willingness of NCA5 authors to promote alarm, but also the ineffectiveness of the review process in not ensuring such statements are removed.

The tone of the Overview chapter hints at the priorities that governed the writing of the entire report. Word counts of the full report are another crude indicator of those priorities

Term	Number of occurrences
Forcing	111
Uncertainty	384
Watts	19
Culture/culturally	854
Equity/equitable	572
Indigenous	890
Sustainable	295
Racism/racial	153

3 OVERCONFIDENCE WHEN STATING CONCLUSIONS

3.1 Inflated certainty levels

Overconfidence in stating conclusions is an endemic problem in NCA5. The authors frequently make sweeping generalizations without appropriate caveats or acknowledging uncertainties. The overconfidence begins with inflated language to describe certainty levels.

NCA5 uses specific terms to convey information about scientific confidence associated with important finds, observations and projections. The Front Matter of NCA5 states that

confidence in a finding is based on the type, amount, quality, strength, and consistency of evidence; the skill, range, and consistency of methods to detect, evaluate, attribute, and interpret climate trends; and the degree of agreement across scientific information sources.

and Table 1 from the Front Matter provides calibrated language for confidence assessment:

Very high:	Strong evidence (established theory, multiple sources, well documented and accepted methods, etc.). High consensus
High:	Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.). Medium consensus
Medium:	Suggestive evidence (a few sources, limited consistency, methods emerging, etc.) Competing schools of thought.
Low:	Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.). Disagreement or lack of opinions among experts.

This terminology is inflated: *high confidence* with just moderate evidence and medium consensus; *medium confidence* with only suggestive evidence and competing schools of thought. This inflation in terminology leads to overconfidence in conclusions.

Even with this inflated terminology, NCA5 further inflates the confidence level of many of its conclusions to well beyond what the IPCC has concluded with more thorough justification, and also by incorrectly applying its own standards. Here are two examples.

Key Message 3.1 Traceable Account states:

There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have unequivocally caused *all* global warming observed over the industrial era.

while the corresponding statements from IPCC AR5 and AR6 are

AR5: It is *extremely likely* that *more than half* of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together.” (IPCC, 2013)

AR6: The *likely* range of total human-caused global surface temperature increase from 1850–1900 to 2010–2019 is 0.8°C to 1.3°C, with a best estimate of 1.07°C. It is *likely* that well-mixed GHGs contributed a warming of 1.0°C to 2.0°C, other human drivers (principally aerosols) contributed a cooling of 0.0°C to 0.8°C, natural drivers changed global surface temperature by –0.1°C to +0.1°C, and internal variability changed it by –0.2°C to +0.2°C. It is *very likely* that well-mixed GHGs were the main driver of tropospheric warming since 1979.

The IPCC AR5 and AR6 statements provide likelihood assessments but not a confidence level. While NCA5 claims with *very high confidence* that fossil fuels have unequivocally caused *all* global warming, AR5 refers to “*more than half* of the observed warming” and AR6 provides a more nuanced statement that relates to a *likely* range of warming contributed to by human drivers.

As a second example, NCA5 Key message 2.2 reads

~~Hurricanes have been intensifying more rapidly since the 1980s (*high confidence*) and causing heavier rainfall and higher storm surges (*high confidence*).~~

~~No justification is provided in Chapter 2 for the *high confidence* conclusion on higher storm surges or hurricanes causing heavier precipitation. The Traceable Accounts section, Description of Confidence and Likelihood states:~~

~~Basic physical understanding and climate models both provide robust explanations for the links between climate change and observed changes in these extremes; this is why the authors also have *high confidence* that storms are delivering more rainfall and high confidence that storm surges are becoming higher.~~

~~In short, NCA5 provides no observational basis or published research for their *high confidence* assertions that hurricanes are causing heavier rainfall and higher storm surges, thus failing to meet its own standards for a *high confidence level*.~~

~~THIS EXAMPLE IS USED IN TRACEABLE ACCOUNTS~~

3.2 Overstating findings in underlying sources

Although we did not do a detailed audit of NCA5's use of source material, spot checks turned up evidence of a pattern of overstatement.

Chapter 2 page 11 reports on an increase in precipitation in some areas and attributes it to human caused climate change:

Many eastern regions of the country are getting wetter (Figure 2.4). Average annual precipitation from 2002-2021 was 5%-15% higher relative to the 1901-1960 average in the central and eastern US, a trend attributable to climate change.⁴

Note that this a non-standard metric; we will discuss NCA5's inconsistent choices of time scales of analysis below. The claims were attributed to the following paper:

- Knutson, Thomas and Fanrong Zeng (2018) "Model Assessment of Observed Precipitation Trends over Land Regions: Detectable Human Influences and Possible Low Bias in Model Trends" *Journal of Climate* 31(12)
<https://journals.ametsoc.org/view/journals/clim/31/12/jcli-d-17-0672.1.xml>

But Knutson and Zeng did not say these things. They examined linear trends over 1901 – 2010, 1951 – 2010 and 1981 – 2010. They did not compare average rainfall over 2002 - 2021 to average rainfall over 1901 – 1960, if only because their study was published in 2018. For 1981-2010, they noted stronger trends in some areas but cautioned that such changes are consistent with natural variability, and they did not claim attributable trends were observed over the United States:

Observed annual precipitation trends over the recent 30-yr period 1981–2010 (Fig. 5) have generally stronger magnitudes (in mm yr⁻¹ decade⁻¹) than observed trends for 1901–2010 or 1951–2010. This is as expected since trends over a shorter period have stronger potential for occurrence of pronounced temporary trends due to internal variability alone. Only 9% of the analyzed area has detectable and attributable anthropogenic influence (categories -3, -2, +2, +3), which represents less than one-third of the fractional areal coverage of such trends for 1901–2010 (29%). ... Eight percent of the analyzed area has attributable anthropogenic *increases* (categories +2, +3), including parts of eastern Europe, northern Asia, northern Australia/Maritime Continent, and tropical Africa.

As another example of overstating findings, NCA5's Chapter 2 page 18 states

There is robust evidence that human-caused warming has contributed to increases in the frequency and severity of the heaviest precipitation events across nearly 70% of the US.

This is allegedly attributed to two papers:

- Diffenbaugh, N.S., D. Singh, and J.S. Mankin, 2018: Unprecedented climate events: Historical changes, aspirational targets, and national commitments. *Science Advances*, 4 (2), 3354.
<https://doi.org/10.1126/sciadv.aao3354>

⁴ Quite separately we note that the attribution to "climate change" is misleadingly ambiguous. Because NCA5's Glossary defines "climate change" as a change in climate for any reason, the statement is a tautology and so the attribution is superfluous. But because the popular perception of climate change is anthropogenic, its gratuitous inclusion effectively attributes the changes to greenhouse gas emissions. [FIX FORMATTING HERE]

- Kirchmeier-Young, M.C. and X. Zhang, 2020: Human influence has intensified extreme precipitation in North America. *Proceedings of the National Academy of Sciences of the United States of America*, **117** (24), 13308-13313. <https://doi.org/10.1073/pnas.1921628117>

Diffenbaugh *et al.* presented ratios of observed occurrences of extreme events to simulated occurrence rates in CMIP6 models run with only natural forcings. They report that for 79% of the U.S. extreme rainfall event frequencies are currently higher than in model simulations, and the ratio of occurrences will rise under future warming simulations. This is not “robust” evidence of anthropogenic influence since it requires readers to assume that climate models provide accurate simulations of regional precipitation patterns, something that even IPCC AR6 admits is uncertain (AR6 WGI SPM Box SPM 1.2, SPM Section C.1.3).

Kirchmeier-Young and Zhang looked at extreme 1- and 5-day events in North America and, using three GCMs, found

A signal of combined anthropogenic and natural external forcing can be detected in the intensification of extreme precipitation at the continental scale over North America. In some cases, this intensification can be attributed to human influence specifically.”

However, they noted large differences among the three models in their simulated precipitation changes. Also, two of the three models failed to yield attribution for 5-day events for the North America mean. In other words the models disagreed on whether the observed changes were due to anthropogenic activity. Both cited references utilized the implausible RCP8.5 scenario and began their “historical” observational records only in 1961. Here again this is not “robust” evidence, it is merely suggestive, particularly since other studies have found natural variability predominant.

3.3 Technical example: Emergent constraints

Some of the overconfidence expressed by NCA5 arises by omitting discussion of counterevidence in the peer reviewed literature. An example is the topic of “emergent constraints”. Chapter 3 page 17 invokes this concept to support its claim that key uncertainties have been reduced:

An approach to reduce uncertainty in climate change projections has matured over the past decade. It is known as “emergent constraints.” The term refers to strong statistical relationships between highly uncertain future climate parameters and observable trends or variations in the current climate, along with a physical explanation of this relationship.

Emergent constraints appeared in the climate modeling literature as an attempt to tie GCM behavior to climate observations in hopes of generating insight into real-world ECS equilibrium climate sensitivity to a doubling of carbon dioxide (ECS). Climate models exhibit a wide range of sensitivities ECS values. The idea of emergent constraints is to examine whether the models with shared sensitivity values also share a common representation of some climate process (usually related to clouds) that might indirectly influence ECS. Suppose, for instance, that in low-ECS models the total cloud fraction in the tropics is strongly correlated with that in the southern midlatitudes but in high-ECS models the correlation is weak. Then researchers could examine whether check if the observed correlation is strong or weak and draw a conclusion about which type of model, and therefore which ECS value, is more likely.

A problem in the emergent constraint literature is that there has been a proliferation of proposed correlations with little physical motivation. Many emergent constraints patterned on CMIP5 models failed to work on CMIP6 models (Schlund *et al.* 2020)⁵. In other words, the observed correlations in CMIP5 models between ECS and cloud processes failed to show up in CMIP6 models, indicating that they were likely spurious rather than clues to physical processes governing the Earth climate system. The result was that emergent constraints estimated from CMIP5 models widened the range of estimated ECS values when applied to CMIP6 models.

Schlund *et al.* summarized the problem as follows [**boldface** used for emphasis]

In this study, we systematically analyze 11 published emergent constraints on ECS that have mostly been derived from models participating in the Coupled Model Intercomparison Project Phase 5 (CMIP5) project... The focus of the study is on testing if these emergent constraints hold for [Earth System Models] participating in the new Phase 6 (CMIP6). Since none of the emergent constraints considered here have been derived using the CMIP6 ensemble, CMIP6 can be used for cross-checking of the emergent constraints on a new model ensemble. **The application of the emergent constraints to CMIP6 data shows a decrease in skill and statistical significance of the emergent relationship for nearly all constraints, with this decrease being large in many cases.** Consequently, the size of the constrained ECS ranges (66% confidence intervals) widens by 51% on average in CMIP6 compared to CMIP5.

Yet NCA5 described the use of emergent constraint analysis as a great “advance” that reduced uncertainty.

⁵ Schlund, Manuel, Axel Lauer, Pierre Gentine, Steven C. Sherwood, and Veronika Eyring (2020) Emergent constraints on equilibrium climate sensitivity in CMIP5: do they hold for CMIP6? *Earth System Dynamics* 11 1233-1258 <https://doi.org/10.5194/esd-11-1233-2020> [Need to be consistent on where references go]

4 RELIANCE ON *Ad Hoc* TIME SCALES FOR TREND ANALYSIS

In CWG25 Chapter 6 we discussed the need for care in the choice of time scale when making claims about trends in extreme weather. We gave provided examples from analysis of river flooding {6.1}, heatwaves {6.3}, and extreme precipitation {6.4} to show how assertions about apparent trends based on short data sets fall apart when looking at longer versions of the same data sets. Here we elaborate on these examples to illustrate the general point that NCA5 made inconsistent and *ad hoc* choices about time scales of analysis, weakening the validity of their conclusions.

McKittrick and Christy (2019)⁶ CWG25 Section 6.x showed that apparently significant positive trends in U.S. average and extreme precipitation over the NCA4 interval (1901 – 2016) disappeared on longer samples (extending back as far as the 1840s, depending on location) or on a shorter interval coinciding with the final 40 years of the data then available (1978 – 2017).

In CWG Section 6.4 we presented analyses of updated data for the same locations (and many others), in all cases finding both considerable regional heterogeneity and that trends detectable on one time scale are often not detected on longer or shorter time scales. These findings argue against simple attribution of changes to anthropogenic influences.

4.1 Average and Extreme Precipitation

Under Key Message 2.2 “Extreme Events Are Becoming More Frequent and Severe” (p. 2-16) NCA5 states (p. 2-18):

Rainfall is becoming more extreme

Since the 1950s, there has been an upward trend in heavy precipitation across the contiguous US. This increase is driven largely by more frequent precipitation extremes, with relatively smaller changes in their intensity.

NCA5 did not continue the NCA4 precedent of using the post-1901 interval as the time scale for its precipitation discussion; instead it refers to changes “since the 1950s”; NCA5 Figure 2.8 suggests 1958 as the start date. For the present report we have extended the CWG25 analysis even further to include 141 stations across the US in the Pacific Coast, Midwest, Northeast and Southeast regions. We provide details in Appendix 3; here we note merely that once again it is possible to find trends that support the NCA5 position, but they are not robust to selecting longer or shorter time scales of analysis. Data from 1950 to 2024 yields many indications of increased average and extreme precipitation at individual stations and region-wide averages. But when using the entire data set (back to the 1890s or earlier, depending on location) or the later subset (1980 to 2024) the trends become smaller, in many cases they become statistically insignificant, and occasionally they even change sign. Only in the Northeast region are the post-1950 trends robust to also focusing on trends during the post-1980 interval.

The following is a more accurate summary of what U.S. data show.

⁶ McKittrick, R., and J.R. Christy (2019). Assessing changes in US regional precipitation on multiple time scales. *Journal of Hydrology*, 578, 124074. <https://doi.org/10.1016/j.jhydrol.2019.124074>

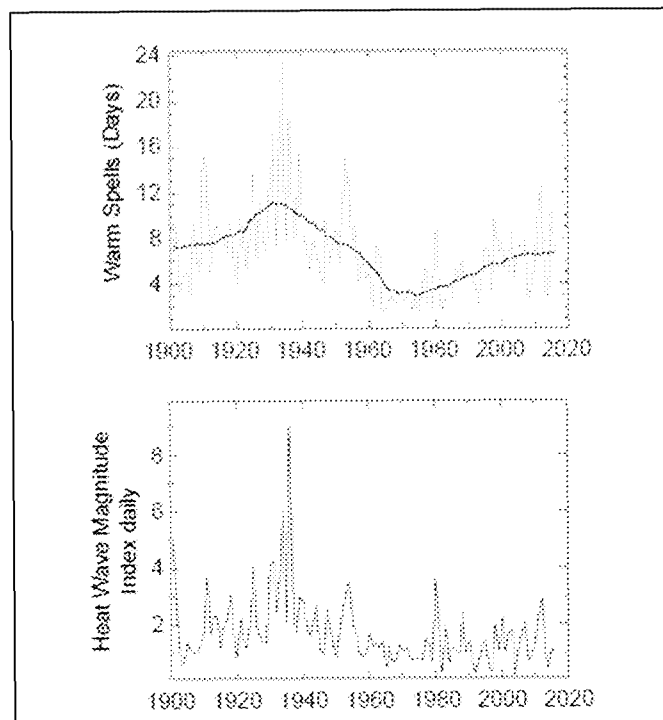
There are regionally heterogeneous changes in average and extreme precipitation. Positive trends in annual average rainfall and extreme events (defined either as the annual maximum or the number of exceedances of the 99th percentile value) are generally weak or non-existent when looking at samples exceeding 130 years in length. Significant trends can be found when beginning the sample in the 1950s although in most cases the trends weaken and become insignificant when looking at the post-1980 interval. This makes attribution of changes in precipitation to anthropogenic warming difficult.

4.2 Heatwaves

In contrast to NCA5, NCA4 examined heat extremes across the whole of the entire 20th century, pointing out that peak heat wave activity was reached in the 1930s and has decreased since then, and that recent increases are confined to areas west of the Rockies:

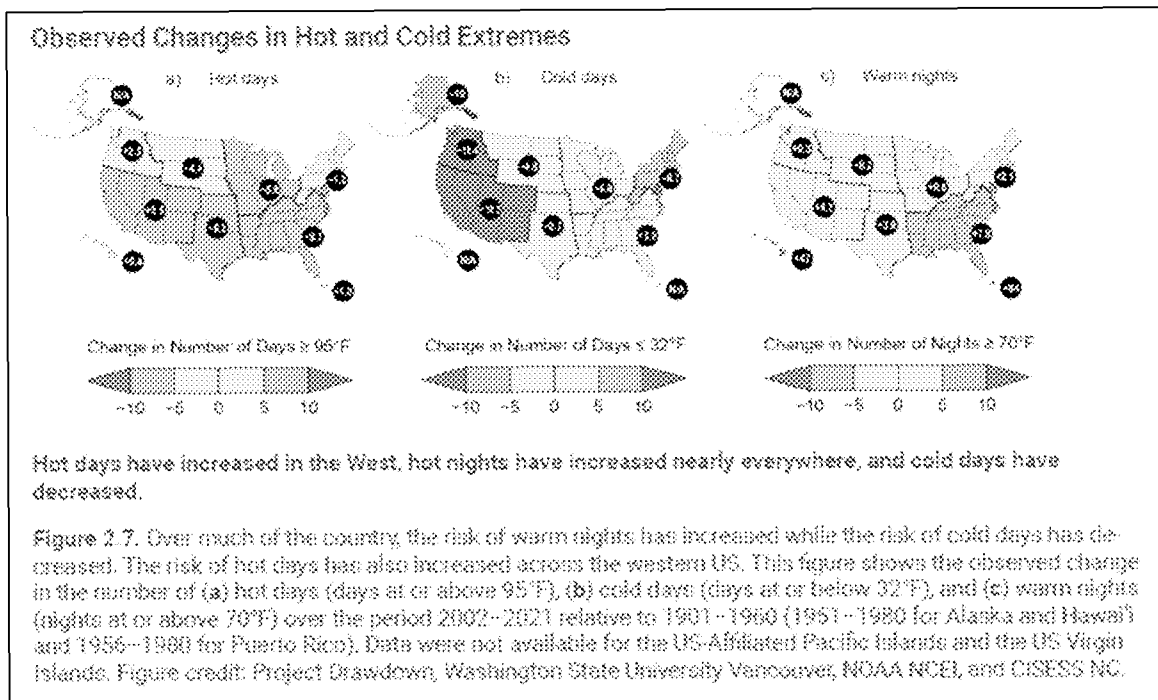
[The] warmest daily temperature of the year increased in some parts of the West over the past century, but there were decreases in almost all locations east of the Rocky Mountains. In fact, all eastern regions experienced a net decrease, most notably the Midwest (about 2.2°F [1.2°C]) and the Southeast (roughly 1.5°F [0.8°C]).

Since the mid-1960s, there has been only a very slight increase in the warmest daily temperature of the year (amidst large interannual variability). Heat waves (6-day periods with a maximum temperature above the 90th percentile for 1961–1990) increased in frequency until the mid-1930s, became considerably less common through the mid-1960s, and increased in frequency again thereafter. As with warm daily temperatures, heat wave magnitude reached a maximum in the 1930s. (NCA4 pp. 190-191)



U.S. Heat waves since 1900. Source: NCA4 Figure 6.4

Contrast this careful and factual language with NCA5 Key Message 2.2: “Extreme Events Are Becoming More Frequent and Severe.” This blanket statement is followed by NCA5 Figure 2.7 (reproduced below) which shows the number of hot days, cold days and warm nights (respectively in panels a—c) over the period 2002–2021 compared to 1901–1960. [Presumably these are annual counts, although not stated in the caption.]



Close inspection shows that this figure contradicts the NCA5 Key Message with respect to heatwaves and instead reinforces the position of NCA4. Notwithstanding Key Message 2.2 the leftmost panel in Figure 2.7 above shows that over most of CONUS the number of extreme heat days has decreased in recent decades compared to the prior century.

The accompanying discussion in NCA5 becomes convoluted as it appears to be aimed at supporting the Key Message despite the contrary evidence. NCA5 chapter 2 elaborates on Key Message 2.2 by saying (page 16):

Observations show an increase in the severity, extent, and/or frequency of multiple types of extreme events. Heatwaves have become more common and severe in the West since the 1980s (*high confidence*).

But it fails to mention **WHAT DECLINE** the decline elsewhere. Instead, it says on the next page (page 17): **THIS POINT IS UNCLEAR**

By some measures, the most extreme heatwaves on record in the United States occurred during the Dust Bowl era of the 1930s. ... Globally such heatwaves are becoming more frequent, and in recent decades the western United States has been following those trends.

The reference to a global trend seems to be an attempt to tie heatwaves to climate change. But the obvious question, unaddressed by NCA5, is why ~~it~~WHAT?? holds for only part of the U.S. while most of the country is trending in the opposite direction. These issues are addressed in Chapter 6 of CWG25, demonstrating that the range and magnitude of extreme temperatures (10s of degrees) are driven more by natural variability than by the small anthropogenic forcing. The analysis in CWG25 shows that for both (a) hot days ($\geq 95^{\circ}\text{F}$) and (b) number of days in heatwaves, the current decade is no hotter than a century ago. For example, during the 30-year period 1925-1954 (only 23% of the 1899-2024 data record), CONUS experienced 33% of the total heat wave days and during the most recent 30 years it experienced 24%, almost exactly that expected by chance. Thus, the NCA5 claim that “multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades,” is simply false when expanding the temporal and spatial domains to encompass all available data (Chapter 6 and Figure 6.3.6 of CWG25).

NCA5 then pointed to the dramatic Pacific Northwest heatwave of 2021. CWG2025 Section 8.6.1 discussed this event in detail, reviewing the multiple peer reviewed studies that explained the unusual meteorological context was unrelated to human-caused climate change, a point omitted from the NCA5 discussion.

NCA5 finally ~~turns to~~ addresses the declining heatwave trend in CONUS east of the Rockies but attempts to reframe it by focusing on urban warm spells.

[The] number of very hot days has actually decreased across the central and eastern regions due to summer cooling trends in the region (Figure 2.7; Ch. 22). This does not, however, mean the central and eastern US are not affected by heat. The impacts of extreme high temperatures are more severe if such conditions persist for several days, and overall, multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades. Across 50 large US cities, the US Global Change Research Program heatwave indicator (<https://www.globalchange.gov/indicators/heat-waves>) shows that the average number of heatwaves has doubled since the 1980s, and the length of the heatwave season has increased from about 40 days to about 70 days.

We discussed ~~this issue~~ WHAT ISSUE in CWG25 Section 6.3. The figure referenced by NCA5 uses an *ad hoc* definition of heat wave, namely two consecutive days with minimum nighttime temperatures above the 85th percentile, and an *ad hoc* time scale which begins in the 1960s, the coldest decade in the last century, thus suppressing any comparison to the 1930s. Further, nighttime temperatures in urban areas have ~~gone up~~ increased faster than daytime temperatures (which NCA5 acknowledges), but this is a signature of urban heat islands and not a good metric of climate change. CWG25 noted as well that the occurrence of hot days ($\geq 95^{\circ}\text{F}$) has recently increased in the West, but declined in the remainder of the country, and in the nationwide average, since 1899.

5 INADEQUATE TRACEABLE ACCOUNTS

NCA3 began the practice of including a section on Traceable Accounts at the end of each chapter. This is the description from NCA5:

Each chapter concludes with a section entitled Traceable Accounts, which provides information on the overall process used to develop the chapter as well as a separate Traceable Account section for each Key Message. These Traceable Accounts describe the supporting evidence behind each Key Message, the process and rationale authors used in reaching their conclusions, and the author team's expert assessment of the confidence in and, where applicable, likelihood of these conclusions. As such, Traceable Accounts provide information about the state of the science, document sources of uncertainty, identify research gaps, and allow traceability to data and resources.

The Traceable Accounts for each chapter and Key Message includes the following sections:

- Description of Evidence Base
- Major Uncertainties and Research Gaps
- Description of Confidence and Likelihood

The Traceable Accounts could in principle address the statutory requirement that the NCA discuss scientific uncertainties. They could also help satisfy the Executive Order for Restoring Gold Standard Science by addressing reproducibility, transparency, communication of error and uncertainty, and skepticism of findings and assumptions. However, the Traceable Accounts in NCA5's Chapters 2 and 3 (the only chapters investigated here) are uneven, often superficial and noninformative.

An example of a deficient Traceable Account is NCA5's Key Message 2.2: "Extreme Events are Becoming More Frequent and Severe". The "Description of the Evidence Base" offers two paragraphs, the first summarizing the findings and the second generically describing the types of data that can be used for storms. "Major Uncertainties and Research Gaps" focuses on the uneven distribution across U.S. populations due to differences in exposure and vulnerability. The only limitations in data referred to are the lack of a long-term record of lightning and the lack of homogenized daily and hourly temperature data apart from reanalysis products.

But the most astonishing deficiency is in the "Description of Confidence and Likelihood." One of the statements in Key Message 2.2 is:

Hurricanes have been intensifying more rapidly since the 1980s (high confidence) and causing heavier rainfall and higher storm surges (high confidence).

The Description of Confidence and Likelihood includes the following statement:

Basic physical understanding and climate models both provide robust explanations for the links between climate change and observed changes in these extremes: this is why the authors also have high confidence that storms are delivering more rainfall and high confidence that storm surges are becoming higher.

No reference to journal publications or a specific data set is made in the Chapter regarding hurricane induced precipitation or storm surge to support this *high confidence* conclusion.

The Traceable Accounts for the various Key Findings of Chapter 3 have some substantial inconsistencies. Consider

Key Message 3-1: Human activities have caused global warming.

Confidence and Likelihood: “There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have *unequivocally* caused all global warming observed over the industrial era. There is also *very high confidence* that changes in natural climate drivers have had globally small and regionally variable long-term effects over this period.”

The Uncertainties section addresses only uncertainties in radiative forcing by greenhouse gases. In contrast, the Traceability Analysis of Key Message 3-4 (“Humans Are Changing Earth System Processes”) is arguably the most scientifically credible text in the entire Chapter. From its Description of Evidence Base:

In the last decade, there has been increasing recognition of the role of regional-scale natural variability in the past and future evolution of climate, as well as the fact that regional natural variability signals can be competitive with forced anthropogenic signals.

And from its Major Uncertainties and Research Gaps:

For example, the true natural variability of the climate system on decadal to centennial timescales could be larger than what we estimate from GCMs, which would further increase the irreducible uncertainty stemming from natural variability.

There is also a generic problem in tracing NCA5’s Traceable Accounts. The Front Matter of NCA5 states:

Each figure and some tables are accompanied by a metadata survey, which can be accessed in the online version of the report by clicking on the eyeball icon above the figure or table (see the table below for explanations of additional icons used throughout the report). The metadata survey describes data sources, figure or table development methods, copyright information, and other important documentation.

Upon clicking on the eyeball icon above a particular figure, a “Contact Us” email appears, addressed to the USGCRP. No attempt was made to send a email to elicit the Metadata information, but it is clear that this information is not readily accessible online.

In summary, the Traceable Analyses examined here, with few exceptions, fail to meet the stated objectives set forward by the NCA.

6 OVEREMPHASIS ON EXTREME SCENARIOS

To respond to the GCRA mandate to “project major trends for the subsequent 25 to 100 years,” NCA5 relies on projections of future climate change based on estimates of future emissions (the so-called SSP scenarios) and/or specified levels of radiative forcing (the RCP scenarios). For the most part, NCA5 uses scenarios developed for the IPCC Assessment Reports.

In CWG Section 3.2.1 we presented a critical assessment of past and current IPCC scenario envelopes, showing that they have tended to overshoot observed emissions. The IPCC AR6 published in 2021 stated that “The likelihood of high-emission scenarios like RCP8.5 and SSP5-8.5 is considered low in light of recent energy sector developments.” and that same year UN Climate Negotiators (COP) stopped using scenarios above 4.5.

NCA5 makes the following observations about the scenarios they use:

NCA5 authors were advised to assess the full range of scenarios available. (Front Matter)

Scenarios of future emissions and land-use change are developed as plausible alternatives, but no relative likelihood is attached to them. Some recent studies, however, have argued that the highest scenario, SSP5-8.5, is no longer plausible without a reversal of current trends in the adoption of renewables and energy efficiency. (Key Message 3.3 Traceable Analysis)

Despite acknowledging the issue, NCA5 otherwise ignored the problem. A keyword search of NCA5 of mentions of RCP/SSP scenarios finds over 50% referred to the extreme emissions scenarios RCP8.5/SSP5-8.5. Further, 10 NCA5 figures (5.2, 6.9, 7.4, 11.3, 14.6, 22.13, 22.19, 27.9, 29.13) included *only* the 8.5 scenarios:.

The problem of relying on extreme scenarios is particularly acute for NCA5’s sea level rise projections. The sea level rise scenarios used in NCA5 do not relate directly to the SSP emissions scenarios, but rather to specified amounts of sea level rise by 2100. Table 4 of NCA5’s “Guide to Using this Report” reproduced below shows that Low relates to 0.3 m (0.98 feet), Intermediate-Low relates to 0.5 m (1.64 feet), Intermediate relates to 1.0 m (3.28 feet), Intermediate-High relates to 1.5 m (4.92 feet), and High relates to 2.0 m (6.56 feet).

Table 4. Descriptive Terms for Common Sea Level Rise Scenarios Used in NCA5						
Future global mean sea level rise and sea level rise along United States coastline are shown for five scenarios in feet (and meters), relative to a 2000 baseline. The US values shown in the right half of the table are averaged across the US coastal regions, including the contiguous US, Alaska, Hawaii and the US-Affiliated Pacific Islands, and the US Caribbean. The national values shown in the table differ substantially from regional values. For example, sea level rise is higher in the Gulf Coast and lower or even negative in some parts of Alaska. In the next 30 years (2020–2050), sea level along the contiguous US coasts is expected to rise 0.92 feet (0.28 m), the same amount of sea level rise observed over the last 100 years (1920–2020). See Chapter 9 for regional sea level information. Adapted from Sweet et al. 2022. ¹						
Sea Level Rise Scenario Descriptors	Global Mean Sea Level			United States		
Year	2050	2100	2150	2050	2100	2150
Low	0.49 (0.15)	0.98 (0.3)	1.31 (0.4)	0.59 (0.18)	0.98 (0.3)	1.64 (0.5)
Intermediate-Low	0.66 (0.20)	1.64 (0.5)	2.62 (0.8)	0.75 (0.23)	1.64 (0.5)	2.95 (0.9)
Intermediate	0.92 (0.28)	3.28 (1.0)	6.23 (1.9)	0.89 (0.27)	3.28 (1.0)	6.89 (2.1)
Intermediate-High	1.21 (0.37)	4.92 (1.5)	8.86 (2.7)	1.12 (0.34)	4.92 (1.5)	8.86 (2.7)
High	1.41 (0.43)	6.56 (2.0)	12.14 (3.7)	1.38 (0.42)	6.56 (2.0)	12.46 (3.8)

Table 4 from the Front Matter of NCA5

Considering only projections representing processes quantified with at least medium confidence, IPCC AR6 assessed global mean sea level projections for 2100 to fall between 0.2 and 1.6 m (5th—95th percentile range). Nevertheless, the range of sea level rise scenarios considered by NCA5 extends to 2.0 m. Further, NCA5 fails to include plausible lower scenarios, such as 0.2 m cited by the IPCC, which also corresponds to the average rate of sea level rise over the past century.

Chapter 9 of NCA5 offers the following predictions of sea level rise:

“Under a range of potential global warming levels, average sea level along US coastlines is *likely* to be between 12 and 20 inches above 2000 sea levels in 2050 (Figure 9.2).”

These values span from the Intermediate scenario to values slightly greater than the High scenario. They can be put into context by considering the observed global sea level rise from 2000-2024, approximately 3.39 inches (0.28 feet). NCA5 is thus projecting a sea level rise during 2025 and 2050 that is 3.5 to 5.8 times the rate observed during 2000-2024. Chapter 9 further states:

“Looking toward the future, an 11 inch (28 cm) average rise along the contiguous US coastline is expected by 2050 (relative to 2020), with a *likely* range of 9-13 inches.”

...

“There is *high confidence* and it is *likely* that sea levels will rise about 11 inches (likely range of about 9–13 inches) between 2020 and 2050”

In summary, NCA5 presents future sea level rise scenarios that are not directly relatable to either SSP/RCP emissions scenarios nor to global warming levels. The NCA5 scenarios include two scenarios that are higher than the 95th percentile for the extreme emissions scenario RCP8.5 and include hypothesized ice sheet processes in which there is low confidence. Projections to 2050 require rates of sea level rise from 2025 to 2050 that are more than triple the rate observed during 2020-2024. Further, NCA5 ascribes *high confidence* to these sea level rise projections.

More generally, NCA5's inclusion, and even focus, on implausible extreme emissions scenarios supports projections of alarming impacts that are very unlikely to be driven by anthropogenic warming.

7 INADEQUATE NASEM REVIEW: TO BE ADDED

I THINK WE SHOULD DELETE THIS CHAPTER, IT ISN'T VERY STRONG

The National Academies of Science, Engineering and Medicine (NASEM) undertook a detailed review of the draft NCA5 (NASEM 2023).⁷ While they raised some of the same concerns that we have articulated herein, their review is superficial overall and appears to be written by authors who share many of the biases of the NCA5 team. There is an inordinate focus on social and policy issues (e.g., every chapter is assessed under the heading "Comments on Equity and Justice"), rather than on the underlying science. In our assessment NASEM failed to apply the serious rigor one would expect. A few extracted comments from it will illustrate. Note that NASEM review comments are included here in blue font for reference.

7.1 Substantive criticisms by NASEM

- summarize the valid points made by NASEM and check the NCA replies

7.2 Failures to challenge NCA5 flaws

NASEM praised Chapter 2, saying:

The chapter [2] meets the requirements of Section 106 of the GCRA.

Yet contrary to the requirements of Section 106, NCA5 Chapter 2 did not adequately discuss natural variability let alone assess the full climate record available for quantifying natural variability. Chapter 2 actually minimizes natural variability by claiming (unsubstantiated) skill in attributing recent extremes to human causes. For example NCA5's Chapter 2 Introduction states,

"...recent advances in attribution science (KM 3.3) mean that the role of climate change in some extreme events can now be quantified in real time. For example, climate change made the record-breaking Pacific Northwest heatwave of June 2021 2° to 4°F hotter, and in 2017 ..."

CWG25 reviews the expert literature demonstrating that this particular event would have happened with or without climate change and that for CONUS, hot extremes are no more frequent now than they were in the past. NASEM did not challenge the unsubstantiated attribution claims in NCA5.

Notwithstanding NASEM's claim that the Chapter complies with Section 106 of the GCRA, it then acknowledged the absence of discussion of natural variability:

⁷ National Academies of Sciences, Engineering, and Medicine. 2023. *Review of the Draft Fifth National Climate Assessment*. Washington, DC: The National Academies Press. <https://doi.org/10.17226/26757>.

...the discussion and references regarding the role of natural climate variability and its regional differences are missing.

While a nod to natural variability is occasionally found in NCA5, it is usually followed by a “however” to emphasize human influence. One example is the statement just before the claim mentioned above pertaining to extreme event attribution: “There has always been extreme weather, which occurs even in an unchanged climate due to the natural variability of the Earth system. However, recent advances in attribution science (KM 3.3) mean that the role of climate change in some extreme events can now be quantified in real time...”

We pointed **REFERENCE THE SPECIFIC SECTION OF THIS REPORT** out that the evidence regarding heatwaves directly contradicts Key Message 2.2. NASEM did not mention this, instead it focused on a somewhat esoteric issue of terminology:

“Extreme Events Are Becoming More Frequent and Severe.”

Key Message 2.2 is another generally well written key message. However, while the title of this key message includes the word “risk,” the key message is exclusively about hazard. The Committee suggests rewriting the key message title to more accurately reflect the discussion on hazards.

The NASEM review appears to accept NCA5’s use of short data records because it makes no critical remarks about the failure to assess long time series, except for its observation that the use of short records makes the omission of natural variability that much more of a problem:

It is also important to point out that the influence of natural climate variability becomes particularly strong when the climate trend is computed based on short periods of time or small geographic areas.

This comment was largely ignored in the NCA5 final text.

In sum, while the NASEM review might bestow the Academies’ imprimatur on the NCA5 report, it does not necessarily add to its quality for two reasons. As we have demonstrated, the NASEM review falls short in rigor and completeness. And second, the NCA authors are not obligated to follow the NASEM recommendations in crafting their final product.

8 SUMMARY EVALUATION OF NCA5

CHAPTER NEEDS A COMPLETE REWRITE

The most straightforward evaluation of NCA5 is through its statutory requirements. While it is not within our purview to make definitive rulings on compliance, we believe there are several important aspects to consider when evaluating NCA5 against its statutory requirements. Add text per Seth's letter ...

~~Our expertise in climate science, the foundational area covered by NCA5, allows a different perspective, one that finds the coverage unbalanced and selective. Our review has identified numerous instances where NCA5 falls short of the quality and integrity expected of scientific document of this importance. Furthermore, our examination suggests that the entire process—from the selection of contributing authors to the handling of expert reviews—appears to have been systematically biased toward reinforcing predetermined conclusions and amplifying alarmist messaging rather than presenting a balanced scientific assessment. In short, NCA5 was written to persuade, not inform.~~

~~A third perspective for evaluating NCA5 is that of citizens interested in good policymaking. The changing climate is a legitimate public concern, as are concerns about cost of living, economic growth, employment opportunities, and other socioeconomic factors. We share the widespread belief that elected officials should have access to the highest quality information when crafting energy and climate policy decisions that must balance multiple concerns. From this perspective, NCA5 is a missed opportunity. What could have been a valuable contribution to informed tradeoffs instead became a misleading advocacy document that corrupts the policymaking process.~~

APPENDICES

APPENDIX 1: Charge to the review

APPENDIX 2: statutory requirements for NCA5

APPENDIX 3: Analysis of U.S. Longterm Precipitation Records
~~DELETE APPENDIX 3. WE SHOULD NOT BE PRESENTING ORIGINAL ANALYSES IN THIS REPORT~~
~~[I'm not sure we need both the tables and multipanel figures here. Is anyone really going to look at the tables? Perhaps they can be eliminated and just keep the figures?]~~

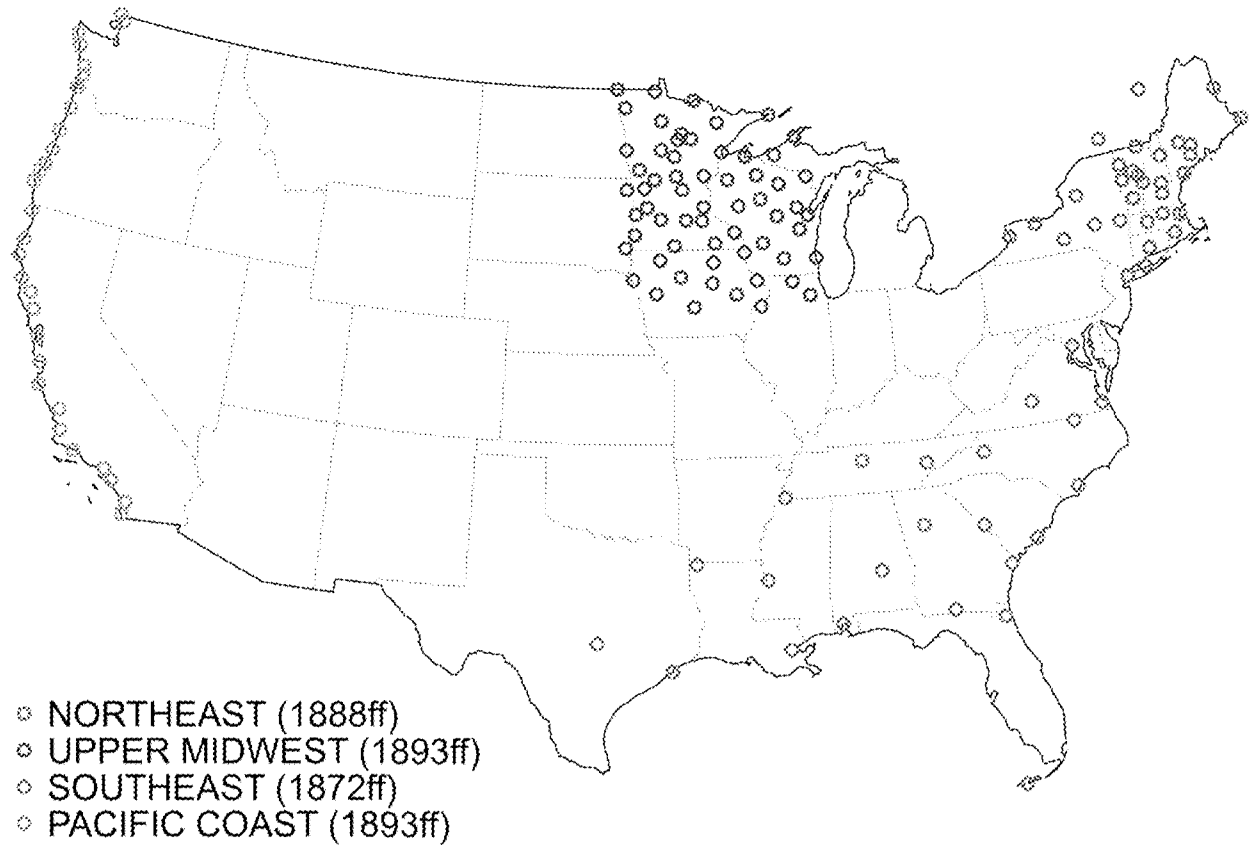


Figure. Stations used in the following analyses.

Table codes: (-) neg insignificant, -- neg significant, (+) pos insignificant, ++ pos significant.

Column 1: Measure

Column 2: Number of stations in that region

Column 3: Count of stations exhibiting a significant positive trend

Column 3: Count of stations exhibiting a significant negative trend

Column 5: Characteristic of region-wide trend

PACIFIC COAST

Since 1893:

	No. stns	+ trends	- trends	region
1-day average	29	0	1	(-)
2-day average	29	0	1	(-)

Avg on non-zero days	29	0	9	--
Variability	29	1	0	(+)
Annual max	29	2	1	(+)
Number of 99 th pct exceedances	29	1	0	(-)

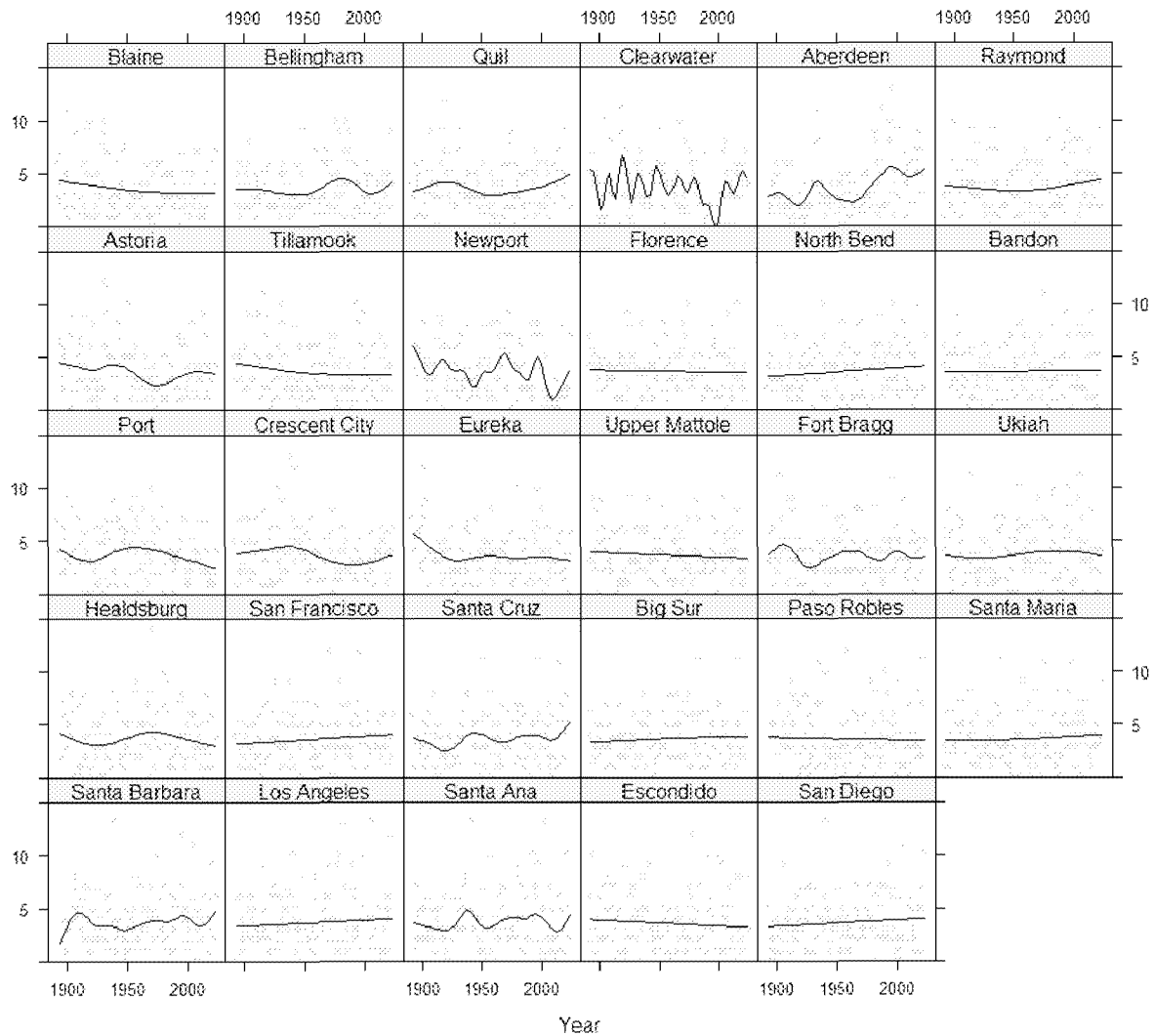
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	29	0	1	(-)
2-day average	29	0	1	(-)
Avg on non-zero days	29	0	4	(-)
Variability	29	2	3	(-)
Annual max	29	6	3	(-)
Number of 99 th pct exceedances	29	2	1	(-)

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	29	0	0	(-)
2-day average	29	0	0	(-)
Avg on non-zero days	29	0	1	(-)
Variability	29	0	0	(-)
Annual max	29	2	1	(-)
Number of 99 th pct exceedances	29	0	0	(+)

Annual No. 99th Percentile Exceedances PC 1893-2024



SOUTHEAST

Since 1873:

	No. stns	+ trends	- trends	region
1-day average	24	1	1	(+)
2-day average	24	1	1	(+)
Avg on non-zero days	24	7	2	(+)
Variability	24	1	0	(+)
Annual max	24	2	0	(+)
Number of 99 th pct exceedances	24	5	0	(+)

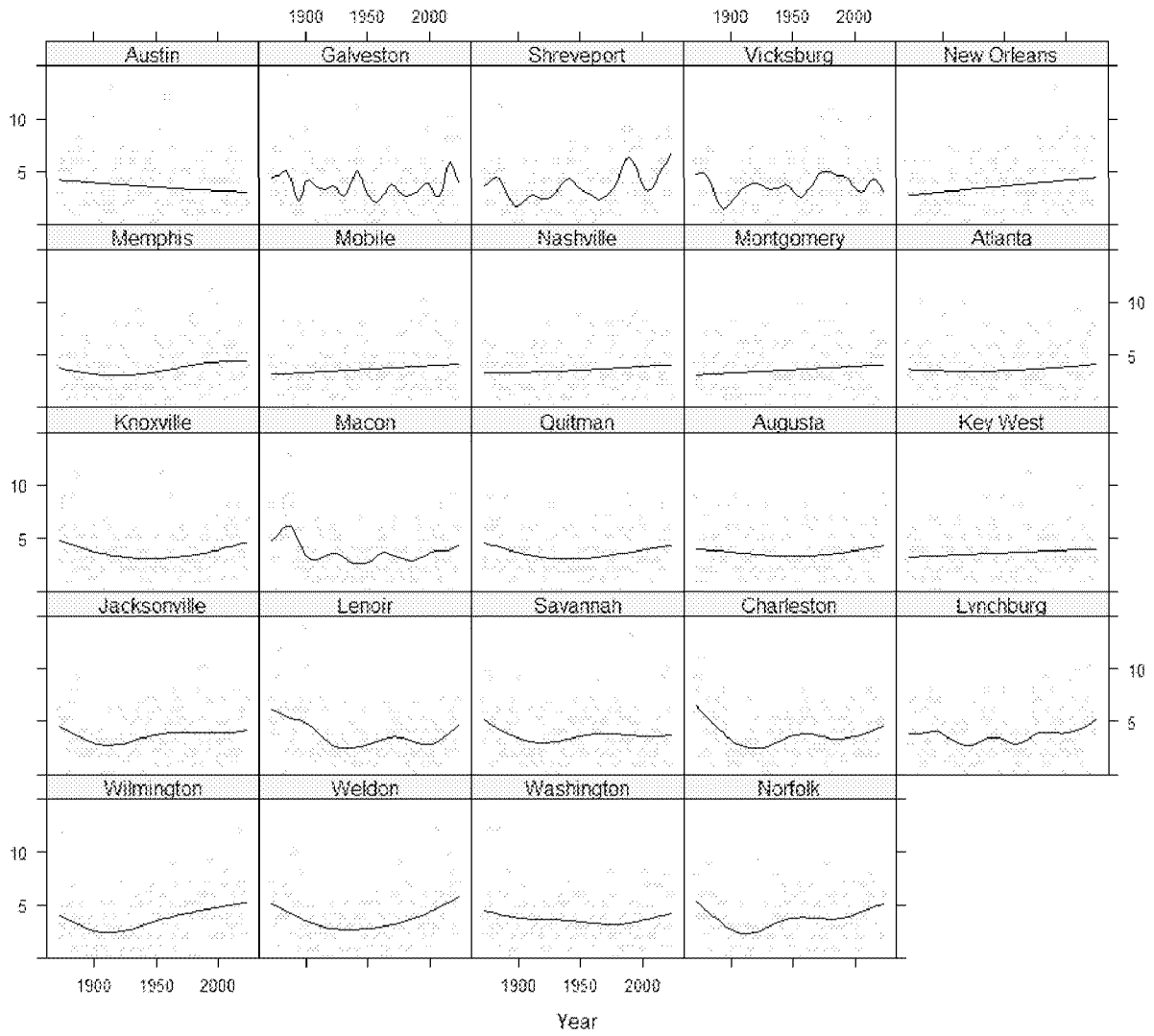
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	24	5	0	++
2-day average	24	5	0	++
Avg on non-zero days	24	5	1	++
Variability	24	6	0	++
Annual max	24	4	0	++
Number of 99 th pct exceedances	24	4	0	(+)

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	24	5	0	(+)
2-day average	24	5	0	(+)
Avg on non-zero days	24	5	1	(+)
Variability	24	3	0	(+)
Annual max	24	4	0	(+)
Number of 99 th pct exceedances	24	4	0	(+)

Annual No. 99th Percentile Exceedances SE 1873-2024



MIDWEST

Since 1893:

	No. stns	+ trends	- trends	region
1-day average	61	23	0	++
2-day average	61	23	0	++
Avg on non-zero days	61	2	12	(+)
Variability	61	12	0	++
Annual max	61	9	0	(+)
Number of 99 th pct exceedances	61	10	0	(+)

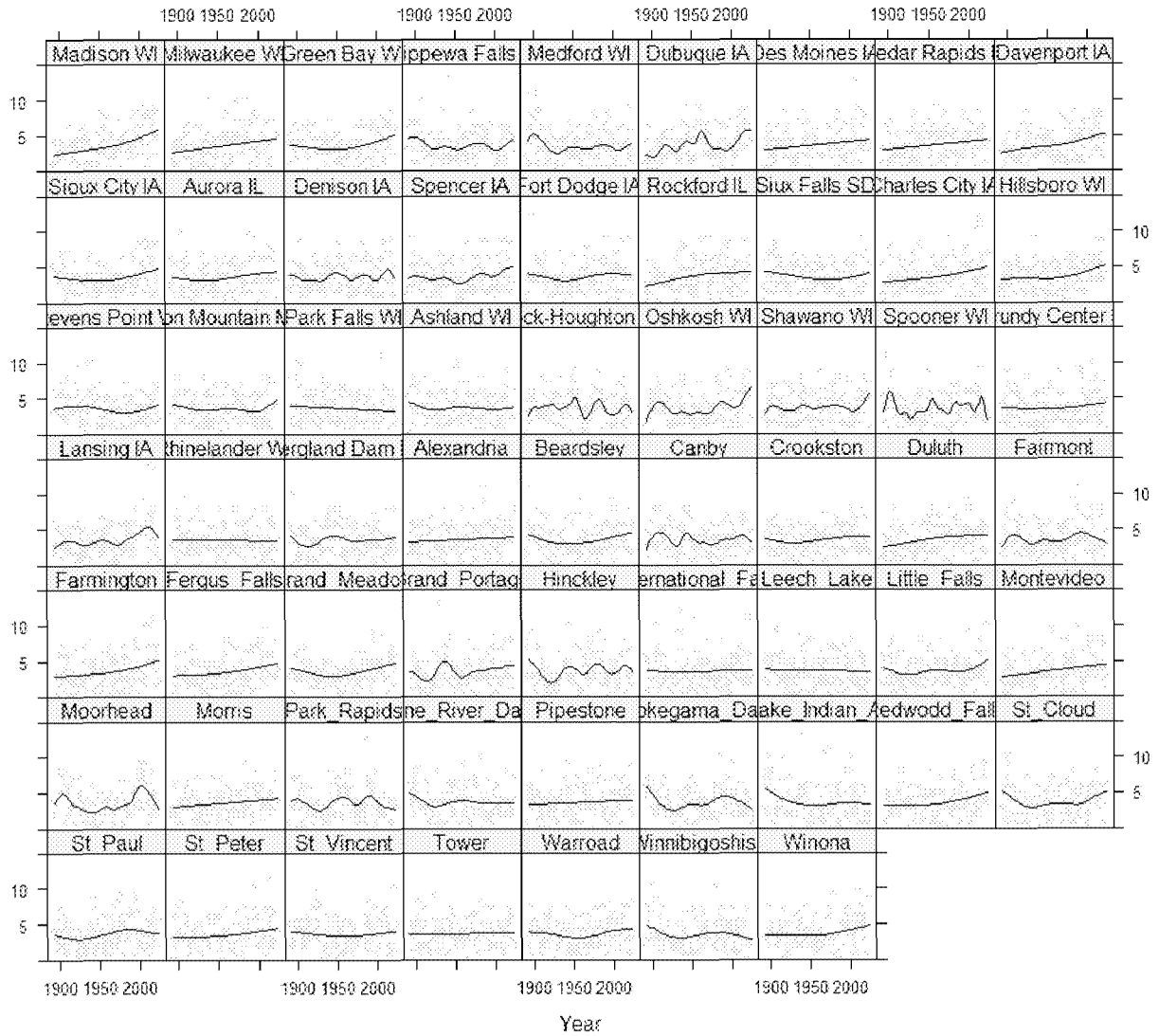
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	61	28	2	++
2-day average	61	28	2	++
Avg on non-zero days	61	11	1	++
Variability	61	16	0	(+)
Annual max	61	8	0	(+)
Number of 99 th pct exceedances	61	19	0	++

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	61	6	1	(+)
2-day average	61	6	1	(+)
Avg on non-zero days	61	8	2	(+)
Variability	61	5	1	(+)
Annual max	61	0	1	(+)
Number of 99 th pct exceedances	61	5	3	(-)

Annual No. 99th Percentile Exceedances MW 1893-2024



NORTHEAST

Since 1888:

	No. stns	+ trends	- trends	region
1-day average	27	12	0	++
2-day average	27	12	0	++
Avg on non-zero days	27	7	1	(+)
Variability	27	4	0	(+)
Annual max	27	3	0	(-)
Number of 99 th pct exceedances	27	5	0	(+)

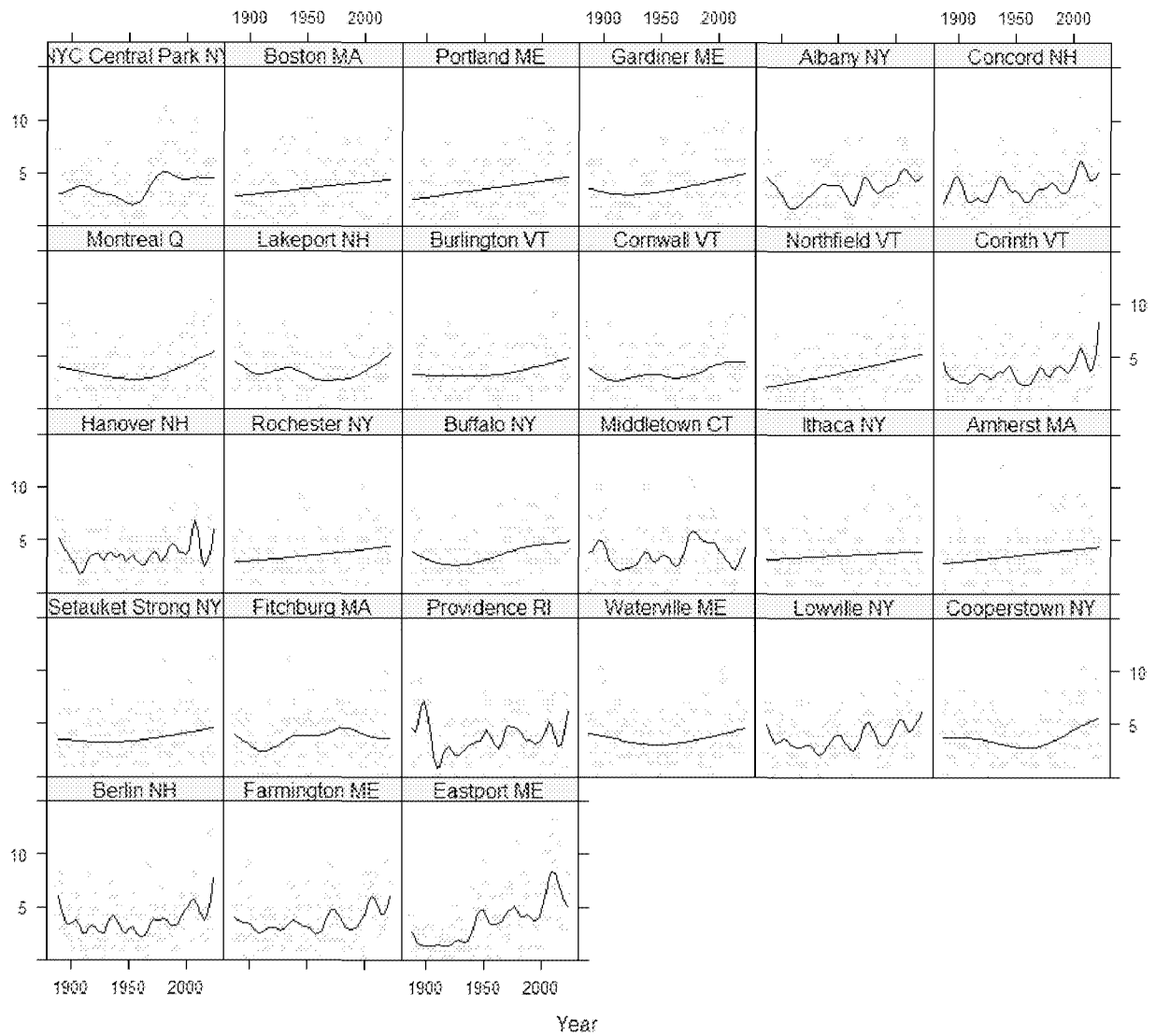
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	27	12	0	++
2-day average	27	12	0	++
Avg on non-zero days	27	7	1	(+)
Variability	27	4	0	(+)
Annual max	27	3	0	(-)
Number of 99 th pct exceedances	27	5	0	++

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	27	10	1	++
2-day average	27	10	1	++
Avg on non-zero days	27	6	0	(+)
Variability	27	2	0	(+)
Annual max	27	1	0	(+)
Number of 99 th pct exceedances	27	1	1	++

Annual No. 99th Percentile Exceedances NE 1888-2024



ABOUT THE AUTHORS

[Insert updated bios]

From: John Christy <climateman60@gmail.com>
Sent: Friday, August 1, 2025 2:52 PM
To: Roy Spencer
Cc: Ross McKittrick; Steven Koonin; Judith Curry; Josh Loucks; Seth Cohen; Travis Fisher
Subject: Re: NCA5 Review TX Floods

All

Cliff Mass has forwarded to me several emails from incensed colleagues at UW who claim we don't know how the radiation budget works, the IPCC was misrepresented etc. I told Cliff to tell those folks to write out their complaints and send them via the portal.

As to records ... funny how they change when you have more data. I recall a reporter who wrote a story about Huntsville weather after I had added 50 years of data - saying, "Huntsvilles records just got hotter, colder wetter and drier"

See you in a minute.

John C.

On Fri, Aug 1, 2025 at 1:41 PM Roy Spencer <roywspencer@hotmail.com> wrote:
Judy just finished a very nice podcast with Heartland. I learned a couple of things.
-Roy

From: Ross McKittrick <ross.mckittrick@gmail.com>
Sent: Friday, August 1, 2025 1:22 PM
To: Steven Koonin <steven.koonin@gmail.com>
Cc: John Christy <climateman60@gmail.com>; Judith Curry <curry.judith@gmail.com>; Roy Spencer <roywspencer@hotmail.com>; Josh Loucks <loucksj14@gmail.com>; Seth Cohen <seth.cohen@hq.doe.gov>; Travis Fisher <travis.fisher@hq.doe.gov>
Subject: Re: NCA5 Review TX Floods

Along the same lines I learned yesterday of the attached study by two Env Canada climate scientists. The extreme event attribution studies of the 2021 Pacific NW heat wave used post-1950 data to estimate the extreme event probabilities. These authors extended the temperature record back to 1940 and found a similar heat wave hit BC, AB and Sk in 1941.



Virus-free www.avast.com

On Fri, Aug 1, 2025 at 2:09 PM Steven Koonin <steven.koonin@gmail.com> wrote:

Oops, hit send too fast-

There was great interest/surprise in the record. So suggest we include these in a box in the final CWG or NCA5 report.

Steven Koonin

> On Aug 1, 2025, at 13:08, Steven Koonin <steven.koonin@gmail.com> wrote:

>

> I have shown the July 1900 observer's report and Roy's graph of the heaviest 2-day events in two separate presentations this week

> Steven Koonin

>

>> On Jul 28, 2025, at 12:29, John Christy <climateman60@gmail.com> wrote:

>>

>>

>> Ross et al.

>>

>> I'm putting the finishing touches on a dataset of 21 stations in Flash Flood Alley (TX) starting in 1893. Data are difficult to find and some forms have never been keyed into computer-readable files, including daily data from the Cotton Region Stations. I'm working on Kerrville today (just down river from Mystic Camp) for data prior to the regular station reports that began in 1902. I ran across this for July 1900 (attached) in which a rain total of 11.60" fell on the 15th and the observer remarked about it.

>>

>> Note he says the river rose 33 ft. Recall the river rose 25ft at Kerrville in the recent July 4th flood. There is already ample evidence that bad floods happen here, but this is an example of data not keyed-in our NOAA official files that can provide better evidence to determine the likelihood of extreme events.

>>

>> In any case, we can use the results of our (i.e. Ross's) analyses of these 21 stations in our review of NCA5 to give an example of what an NCA should be doing to understand and prepare for natural variability vs. climate change (and how pathetic the information was in NCA5.)

>>

>> John C.

>>

>> p.s. Recall that two months later in Sept 1900, the worst hurricane death toll in US history occurred in Galveston. It was a bad year for Central TX.

>> <414780_190007_Kerrville.pdf>

From: John Christy <climateman60@gmail.com>
Sent: Monday, July 28, 2025 2:17 PM
To: Steven Koonin
Cc: Ross McKittrick; Judith Curry; Roy Spencer; Josh Loucks; Seth Cohen; Travis Fisher
Subject: Re: NCA5 Review TX Floods

Steve

There is a bit of confusion as to which/where the 1900 gage was. We can find all of that information depending on how much we dive into this in the review of NCA5 - the 25ft was a quote from an NPR news story simply saying "near Kerrville", but later in the story they did indicate at least a 30ft rise before the gage broke. The Kerrville site USGS 08166200 shows a rise from 1.82ft to 34.29ft or 32.47ft, almost identical to the 1900 event from the observer's notes (not sure of their precision). The Kerrville site USGS 08166140 (above Bear Creek) went from 3.05ft to 34.40ft or 31.35ft. We can likely dredge up the old values from historical records, but clearly, quick rises of 30+ feet are in the historical record. The gage closest to Mystic Camp (08165500, Hunt TX used in NPR story) broke at 5:10am as it went from 7.75ft to 37.52ft.

John C.

On Mon, Jul 28, 2025 at 12:53 PM Steven Koonin <steven.koonin@gmail.com> wrote:
This is great!

But didn't the river hit 34 feet during the recent flood: <https://www.usatoday.com/story/graphics/2025/07/06/texas-cities-flooded-july-4-rain/84484814007/>

And the recent rainfall total was 10-12 inches over 3 days, whereas the 1900 total was 11.6 inches over 1 day.

Steven Koonin

On Jul 28, 2025, at 13:29, John Christy <climateman60@gmail.com> wrote:

Ross et al.

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<414780_190007_Kerrville.pdf>

From: John Christy [climateman60@gmail.com]
Sent: 7/28/2025 6:50:00 PM
To: Steven Koonin [steven.koonin@gmail.com]
CC: Ross McKittrick [ross.mckittrick@gmail.com]; Judith Curry [curry.judith@gmail.com]; Roy Spencer [roywspencer@hotmail.com]; Josh Loucks [loucksj14@gmail.com]; Seth Cohen [seth.cohen@hq.doe.gov]; Travis Fisher [travis.fisher@hq.doe.gov]
Subject: Re: NCA5 Review TX Floods

All

Just finished Kerrville TX data entry. Below are the heaviest 2-day events for 1893-2024. These are the 22 heaviest events (nominal 1 in 6yr occurrence - I used 6 years because it divides into 132 years evenly.). Only one of the events occurred in the 21st century - and just barely. The date represents the second of the two days. The July 4-5 2025 event produced 4.14 inches in Kerrville (which is not the source region for the floods, but representative none the less).

John C.

Kerrville TX

1	1978	8	2	15.80
2	1900	7	15	13.00
3	1936	9	16	12.37
4	1971	8	13	11.69
5	1919	8	22	11.62
6	1921	6	13	9.06
7	1952	9	11	8.90
8	1909	7	23	8.84
9	1965	6	23	8.25
10	1957	10	15	7.90
11	1997	6	23	7.76
12	2002	7	3	7.73
13	1991	12	21	7.67
14	1910	4	1	7.52
15	1980	9	8	7.35
16	1974	5	1	7.13
17	1920	8	8	6.68
18	1988	7	12	6.38
19	1935	6	15	6.37
20	1932	7	3	6.29
21	1955	7	18	6.10
22	1900	4	7	5.93

On Mon, Jul 28, 2025 at 1:17 PM John Christy <climateman60@gmail.com> wrote:
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John C.

p.s. Recall that two months later in Sept 1900, the worst hurricane death toll in US history occurred in Galveston. It was a bad year for Central TX.
<414780_190007_Kerrville.pdf>

From: Ross McKittrick <ross.mckittrick@gmail.com>
Sent: Friday, August 1, 2025 2:23 PM
To: Steven Koonin
Cc: John Christy; Judith Curry; Roy Spencer; Josh Loucks; Seth Cohen; Travis Fisher
Subject: Re: NCA5 Review TX Floods
Attachments: Malinina and Gillett -PNW heatwave.pdf

Along the same lines I learned yesterday of the attached study by two Env Canada climate scientists. The extreme event attribution studies of the 2021 Pacific NW heat wave used post-1950 data to estimate the extreme event probabilities. These authors extended the temperature record back to 1940 and found a similar heat wave hit BC, AB and Sk in 1941.



Virus-free www.avast.com

On Fri, Aug 1, 2025 at 2:09 PM Steven Koonin <steven.koonin@gmail.com> wrote:
Oops, hit send too fast-

There was great interest/surprise in the record. So suggest we include these in a box in the final CWG or NCA5 report.

Steven Koonin

> On Aug 1, 2025, at 13:08, Steven Koonin <steven.koonin@gmail.com> wrote:

>

> I have shown the July 1900 observer's report and Roy's graph of the heaviest 2-day events in two separate presentations this week

> Steven Koonin

>

>> On Jul 28, 2025, at 12:29, John Christy <climateman60@gmail.com> wrote:

>>

>>

>> Ross et al.

>>

>> I'm putting the finishing touches on a dataset of 21 stations in Flash Flood Alley (TX) starting in 1893. Data are difficult to find and some forms have never been keyed into computer-readable files, including daily data from the Cotton Region Stations. I'm working on Kerrville today (just down river from Mystic Camp) for data prior to the regular station reports that began in 1902. I ran across this for July 1900 (attached) in which a rain total of 11.60" fell on the 15th and the observer remarked about it.

>>

>> Note he says the river rose 33 ft. Recall the river rose 25ft at Kerrville in the recent July 4th flood. There is already ample evidence that bad floods happen here, but this is an example of data not keyed-in our NOAA official files that can provide better evidence to determine the likelihood of extreme events.

>>

>> In any case, we can use the results of our (i.e. Ross's) analyses of these 21 stations in our review of NCA5

to give an example of what an NCA should be doing to understand and prepare for natural variability vs. climate change (and how pathetic the information was in NCA5.)

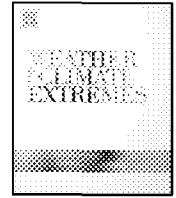
>>

>> John C.

>>

>> p.s. Recall that two months later in Sept 1900, the worst hurricane death toll in US history occurred in Galveston. It was a bad year for Central TX.

>> <414780_190007_Kerrville.pdf>



The 2021 heatwave was less rare in Western Canada than previously thought

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ABSTRACT

The 2021 Pacific Northwest heatwave resulted in record temperatures observed across the Canadian provinces of British Columbia, Alberta and Saskatchewan as well as the US states of Washington and Oregon. Previous studies of extreme temperatures over arbitrarily-defined rectangular regions covering parts of Oregon, Washington and British Columbia have estimated return periods of 200–100 000 years, generally based on data since 1950, with some analyses suggesting that the event would have been considered impossible based on statistical fits to pre-2021 data, or based on climate models failing to simulate such events. We estimate a return period of 1152 (126– ∞) years for the 2021 event averaged over British Columbia, based on a generalized extreme value distribution (GEV) with a location parameter a function of global mean surface temperature fitted to 1950–2021 ERA5 data. British Columbia was the province where the highest absolute temperature of 49.6 °C was measured, and where the largest impacts on human mortality and ecosystems were reported. However, we show that this return period is reduced to 236 (52– ∞) years when the analysis period is extended back to 1940, using newly-available ERA5 data, owing to an extreme heatwave observed in 1941. While the 1941 event was 1.7 °C cooler than the 2021 event in British Columbia, it was a rarer event relative to the cooler climatology of the time, with an estimated return period of 735 (135– ∞) years. Over this longer period we also find that almost all CMIP6 models underestimate variability in annual maximum temperatures over British Columbia. The return period of the 1941 heatwave was comparable to that of the 2021 event in Alberta and Saskatchewan, though not in Washington or Oregon. While the 2021 event was an unprecedented and extremely intense heatwave whose likelihood was much increased by human-induced climate change, our results indicate that this event was not as rare as previously thought in Western Canada.

1. Introduction

In late June 2021 temperatures of almost 50 °C were observed in British Columbia, Canada (e.g. Philip et al., 2022). New Canadian temperature records were set three days in a row in the village of Lytton in Southern British Columbia (BC) from 27 to 29 June 2021 (ECCC Weather BC, 2021a,c,b), with the maximum of 49.6 °C recorded on the 29th of June (WMO, 2021), exceeding pre-2021 record (45.0 °C observed in 1937 in Yellowgrass, SK) by almost 5 °C. Although British Columbia was the hotspot, it was not the only place where record high temperatures were observed. Washington (WA) state, to the south of British Columbia, as well as its southern neighbour Oregon (OR) also experienced record-high temperatures (Philip et al., 2022), as did parts of Alberta (AB) and Saskatchewan (SK) (White et al., 2023).

The extreme heat resulted in a substantial death toll in the region. BC Coroners Service (2022) stated that in the Province of British Columbia 619 deaths were associated with the extreme heat in the period from 25 June to 2 July 2021, and in Washington State 100

deaths were attributed to the heat (Washington State Department of Health, 2021). Additionally, there were reports of extensive damage to marine and terrestrial ecosystems (e.g. Raymond et al., 2022; Sloane et al., 2022).

Because the heatwave was so impactful, in the first year after the heatwave there were several studies which looked at several aspects of the event, including its return period and how much likely it was made by anthropogenic climate change. Most of these studies have focused on TXx (annual maxima of daily maximum temperature) in a rectangular region between 45–52° N and 119–123° W covering parts of British Columbia, Washington and Oregon (Philip et al., 2022; Thompson et al., 2022), or more extensive rectangular regions (McKinnon and Simpson, 2022; Bartussek et al., 2022). In addition to the rectangular region, Thompson et al. (2022) provided analysis of the event rarity in terms of standard deviation using regions from Stone (2019), though their return period analysis was done using the same rectangular region as Philip et al. (2022). While Philip et al. (2022) stress that their

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choice of region was guided by the event's impacts rather than its meteorological extremity, there is nonetheless a danger of selection bias effects associated with the choice of such regions a posteriori (Miralles and Davison, 2023).

Previous studies of the event have used a range of methods to estimate the event's return period from observations. Philip et al. (2022) applied a non-stationary GEV (generalized extreme value) fit to ERA5 over the period 1950–2021, with a location parameter dependent on global mean surface temperature (GMST), and concluded that the event was approximately a 1 in 1000 year event. They also found that a similar fit using 1950–2020 data indicated that an event of the magnitude of the 2021 event was virtually impossible (Philip et al., 2022). Similarly, Thompson et al. (2022) investigated the level of extremity of the event over the same region using ERA5 and JRA55 reanalysis data since 1950. The authors found that the 2021 Western North American heatwave was a 3.6 standard deviation event relative to the surrounding two week period based on 1950–2020 ERA5 data, and was one of the most extreme events recorded globally in terms of standard deviations from climatological values. Bartusek et al. (2022) fitted a non-stationary GEV distribution to ERA5 TXx over a larger region that includes AB and most of BC, and found that the return period of the 2021 event was much larger than 1000 years based on a fit to 1950–2020 data, and about 200 years based on a fit to the 1950–2021 data.

McKinnon and Simpson (2022) examined the rareness of the 2021 heatwave event by looking at the skewness and kurtosis of the maximum temperature at weather stations in the region between 43° N and 57° N and between 115° W and 123° W. They calculated the rareness of the event by comparing the maximum daily temperature in 2021 with the standard deviation of TXx over prior years with varying record lengths across stations. They then examined the CESM2 large ensemble and found that 4.5 standard deviation anomalies comparable to those observed, were approximately 1 in 100 000-yr events in the model.

A number of studies have used either comparisons of single or multi-model large ensembles to estimate risk ratios for the event in the current climate versus the preindustrial climate, finding risk ratios ranging from of least 150 (Philip et al., 2022) to at least 500 000 (Bartusek et al., 2022), as well as to derive projected changes in the frequency of such events under future climate change (Philip et al., 2022; Thompson et al., 2022; Bartusek et al., 2022). Such findings are typically very sensitive to the simulation of realistic variability of such extremes. The other techniques include use initialized simulations to estimate risk ratios or human-induced changes in the intensity of such events (e.g. Bercoff-Hickey et al., 2022) as well as climate model simulations which are initialized with minimal perturbations in the initial conditions to determine if the models can simulate the events of that magnitude (so-called ensemble boosting) (Fischer et al., 2023).

Several studies have examined the synoptic and meteorological reasons for the strength of heatwave (Neal et al., 2022; Lin et al., 2022; Bartusek et al., 2022). The general consensus is that there was a very strong blocking over the region, which allowed the warm air from the low latitudes to penetrate deep to the North (Mo et al., 2022). It has also been suggested that changes in soil moisture contributed to the strength of the observed temperatures (Philip et al., 2022; Bartusek et al., 2022).

Since several aspects of heatwave were already examined in the literature, we focus on several distinct questions here. First, we want to understand the extent of the heatwave, thus, our analysis covers a wider region than the relatively small rectangular regions originally proposed by Philip et al. (2022), McKinnon and Simpson (2022) and Bercoff-Hickey et al. (2022). Second, as suggested by Stone (2019), we concentrate on the political regions (Canadian provinces and the states of the United States of America) rather than on somewhat arbitrary chosen rectangular regions. This choice has the advantage that adaptation policies in Canada and the USA are often applied on the provincial/state level, and it avoids potential selection bias effects

associated with regions defined a posteriori. Second, we leverage the publication of ERA5 data back to 1940 to carry out analysis of the return period back to this earlier start date. And lastly, since this heatwave was a prolonged event, we conduct an attribution analysis not only for TXx, but also for longer periods.

The manuscript is structured as follows: in Section 2 we provide regional information about the heatwave including the its extent and discussion on its duration. The analysis of the rarity of the temperature maxima is presented in Section 3, the evaluation of temperature maxima variability in Section 4 and the attribution results are described in Section 5. The main conclusions are summarized in Section 6. The manuscript contains supplementary material.

2. Spatial extent of the 2021 heatwave

To characterize the heatwave in terms of its spatial extent, duration and strength, we used maximum air temperature at 2 m from the recently updated ERA5 reanalysis (Hersbach et al., 2020b) from 1940 to 2022. Generally, ERA5 has been proven to provide reliable maximum air temperatures over Europe (Velikou et al., 2022), but has also been used in studies focusing on the 2021 heatwave in North America, including Philip et al. (2022) and Thompson et al. (2022). Here, we consider impacted Canadian provinces and USA states using their political borders, not only because it is easier to use the regional numbers for policy making decisions, but also because the temperature patterns were relatively uniform in those regions.

The broad geographical extent of the event is illustrated in Fig. 1, where spatially resolved maximum daily temperature anomalies relative to the maximum observed between 1991 and 2020 in the Canadian provinces of British Columbia, Alberta, Saskatchewan as well as Washington and Oregon states in the USA are shown. These regions were chosen based on the fact that in 2021 within several days from each other they experienced local and regional temperature records and these records were associated with the same synoptic system (Bartusek et al., 2022, Fig. 1). The days shown in Fig. 1 are those on which 2021 temperature maxima occurred in these regions (see also Table 1).

In Oregon, where the maximum was observed on June 28th 2021, the temperature anomalies were positive for the whole region; however, the eastern border region and a small southwest part of the coast experienced lower anomalies than central and northern parts of the state. On June 29th, maxima were observed in Washington and British Columbia. While in Washington the anomalies were around 9 °C for the whole state, in British Columbia more spatial variability is seen. Nonetheless, the whole of British Columbia had positive anomalies on that day and for the most of the province extreme heat alerts were issued. For Alberta, which experienced the highest temperatures on June 30th, similar conclusions apply, with the difference that the central and northern parts of the province experienced higher anomalies rather than the southern border. In Saskatchewan, the largest maximum temperature anomaly was observed on July 2nd 2021. As seen in Fig. 1(d), temperature anomalies on that day were relatively uniform across the province with the exception of three small blue patches corresponding to large lakes. Based on this information, we consider it justified to analyse the heatwave based on temperatures averaged across these states and provinces.

2.1. Heatwave duration

One of the reasons why heatwaves are so deadly is the prolonged heat stress exposure (Koppe et al., 2004; Kenney et al., 2014). According to a commonly used definition (e.g. Perkins and Alexander, 2013; Perkins-Kirkpatrick and Gibson, 2017), a heatwave occurs when three or more consecutive days experience daily maximum temperatures higher than 90th percentile of daily maximum temperature for a 15 day running window surrounding this day during for a base period. Using

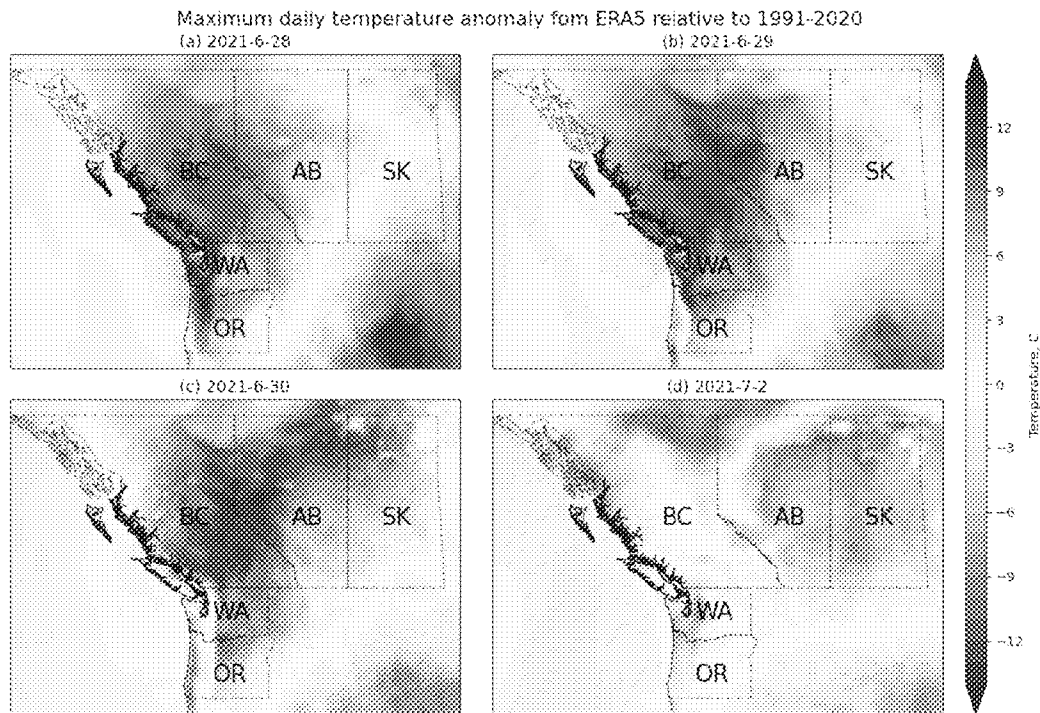


Fig. 1. ERA5 daily maximum temperature anomaly in British Columbia (BC), Alberta (AB), Saskatchewan (SK), Washington (WA) and Oregon (OR). Anomalies are calculated relative to the maximum over the years 1991–2020 over a 31 day period centred on the event.

Table 1

2021 heatwave start dates, end dates, duration and TXx, TX3x and TX7x anomalies based on ERA5 data relative to 1940–1959 for the provinces and states listed.

Region	Start	End	Duration	Peak date	TXx (anomaly)	TX3x (anomaly)	TX7x (anomaly)
BC	6/25	7/1	7 days	06/29	32.1 (9.3) °C	31.5 (9.4) °C	28.9 (8.1) °C
AB	6/25	7/2	8 days	06/30	35.4 (7.0) °C	34.7 (7.2) °C	32.0 (6.1) °C
SK	6/28	7/3	6 days	07/02	33.9 (4.6) °C	33.0 (4.6) °C	30.3 (3.8) °C
WA	6/20	7/1	12 days	06/29	40.2 (8.8) °C	39.1 (8.6) °C	36.0 (6.8) °C
OR	6/25	7/7	13 days	06/28	37.3 (5.0) °C	36.5 (5.0) °C	34.1 (3.6) °C

this definition we calculate the 2021 heatwave duration in the chosen regions with the base period of 1991 to 2020.

As shown in Table 1, the heatwave lasted at least six days in all regions considered, with Oregon and Washington experiencing more prolonged heatwaves lasting thirteen and twelve days respectively. To illustrate the heatwave duration in one of the regions, Fig. 2 shows daily maximum 2-m air temperature for 2021 over the period from June 1st to July 31st (red line, $T_{max}(2021)$) with the 90th percentile of the daily maximum temperatures for the base period (grey line, T_{max} (90th perc 1991–2020)) for British Columbia. The red shaded region shows the longest heatwave of the period. We illustrate the results for that specific region, because according to Table 1 British Columbia experienced the highest anomalies relative to 1940–1959, making the event there most extreme.

Based on this information, and since for most regions the seven day period covers the most extreme heat, we decided to analyse not only TXx or annual maximum daily maximum temperature, but also TX7x, the annual maxima of 7 day average daily maximum surface air temperature, or the warmest week of the year. We also provide analysis of TX3x (the annual maxima of 3 day average daily maximum surface air temperature), a commonly used heatwave characteristic (e.g. Kew et al., 2019; Wehner et al., 2018). Furthermore, the three-day period corresponds to the time frame when in most of the regions the temperature exceeded the 99th percentile.

3. Return period of the 2021 heatwave

3.1. Analysis based on ERA5 data from 1940 to 2022

After averaging the ERA5 daily maximum temperatures over each region, we analysed annual maxima of 1 day, 3 day and 7 day mean daily maximum temperatures (TXx, TX3x and TX7x). In each region for each time series, we fitted a non-stationary generalized extreme value distribution to the data over the period from 1940 to 2022, with the location parameter being linearly dependent on the ERA5 global mean surface air temperature (GSAT) anomalies (Morice et al., 2021) smoothed with a 4 year running mean. The value for 2021 event was included in the fit, although we are aware of the heated discussion in the scientific literature on whether it is the correct approach (Philip et al., 2020; Van Oldenborgh et al., 2021; Miralles and Davison, 2023). We also want to draw the reader's attention to the fact that the 2022 TXx, TX3x and TX7x (i.e. observations from after the event of interest) were also used in the fit. While there is a possibility that the return periods would somewhat change with 2022 data excluded, we wanted to take advantage of as long as possible timeseries to allow for more accurate return period estimates (Philip et al., 2020; Van Oldenborgh et al., 2021; Thompson et al., 2023).

Based on the timeseries and the histograms in Fig. 3, one can see that record TXx values in British Columbia and Alberta occurred in

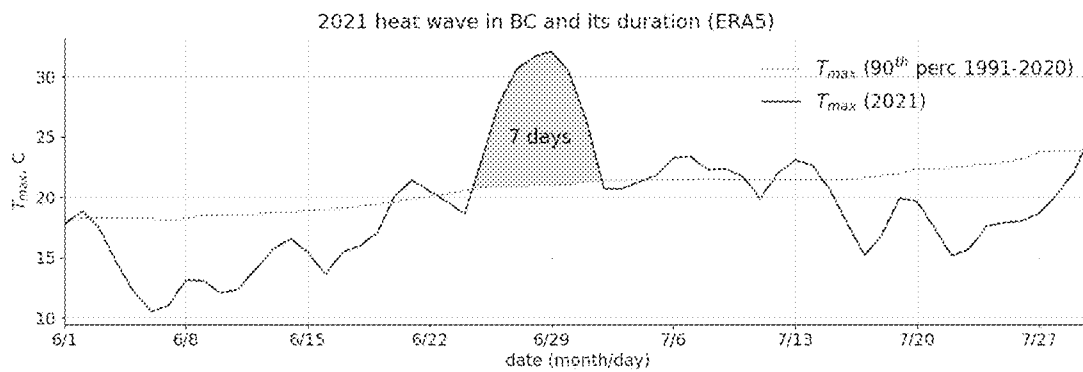


Fig. 2. ERA5 heatwave in British Columbia (BC).

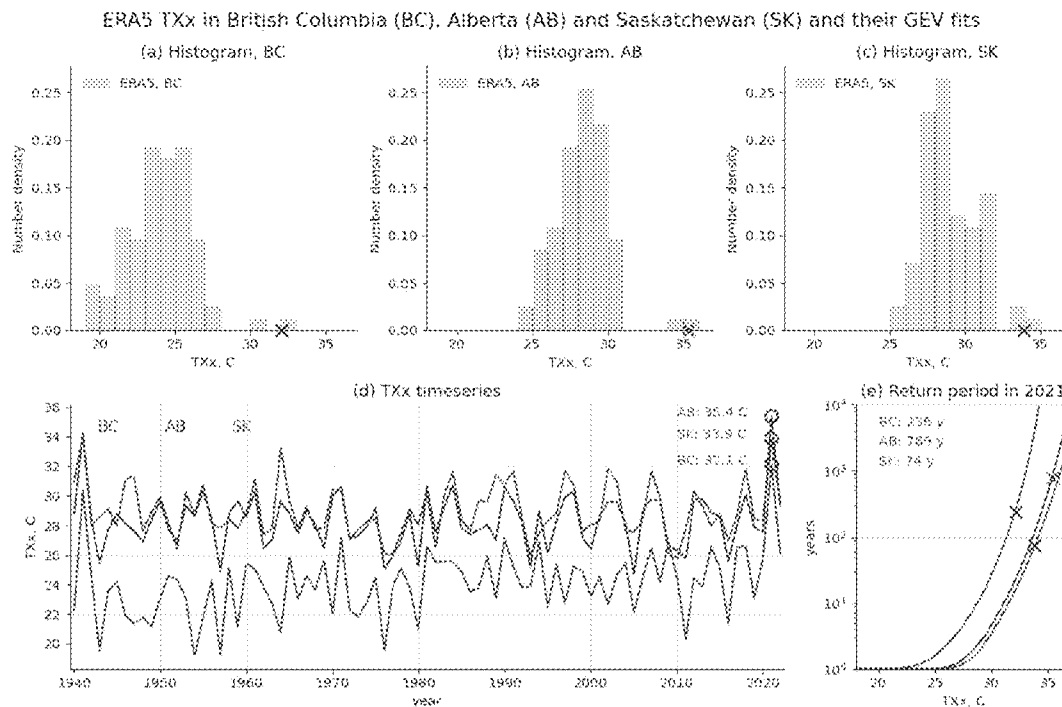


Fig. 3. ERA5 TXx histograms (panels (a)–(c)), timeseries (panel (d)) and return period curves (panel (e)) shown in blue for British Columbia (BC), in red for Alberta (AB) and in green for Saskatchewan (SK). The 2021 values are shown with crosses (panels (a)–(c), (e)) or circles (panel (d)).

2021, however, comparable values were observed in 1941. Furthermore, 1941 was a year of absolute TXx maximum in Saskatchewan based on the ERA5 data, exceeding the 2021 value by 0.1 °C, although 2021 TX3x and TX7x were record maxima in this region. As shown in Fig. 4, 1941 values were not as high in Washington and Oregon, making 2021 an exceptional year in these states. To quantify the rarity of the 2021 values, we calculated the return period of the 2021 TXx, TX3x and TX7x based on the previously described non-stationary GEV fits, using a location parameter corresponding to 2021. The results for each region including corresponding 90% confidence intervals (CIs) estimated by bootstrap resampling all TXx, TX3x and TX7x and corresponding GSAT values with replacement 1000 times are summarized in Table 2. The CIs beginning with > indicate an infinite upper bound. The TXx return period curves for the Canadian provinces and the US states shown in Figs. 3(e) and 4(d) respectively.

In British Columbia, the return period of TXx values as large as in 2021, is 236 (CI: > 52) years. While our return period estimate for British Columbia is noticeably different from those previously published for different rectangular regions (Philip et al., 2022; Thompson et al., 2022; McKinnon and Simpson, 2022; Bercos-Hickey et al., 2022), the 2021 TXx return period of 822 (CI: > 118) years in Washington

is much closer to those estimates. A similar return period of 769 (CI: > 124) years was calculated for Alberta. In Saskatchewan and Oregon the return periods are somewhat lower, namely, 75 (CI: 32–966) and 163 (CI: > 35) years respectively. It is not surprising that Saskatchewan's and Oregon's return periods are lower than those of British Columbia, Alberta and Washington, because those regions were toward the edges of the area affected by the heatwave (see Fig. 3) and their TXx anomalies (see Table 1) were approximately half as large as for British Columbia, Alberta and Washington.

Based on results shown in Table 2, return periods for TX3x were, in general, of the same order of magnitude as those for TXx. For Canadian provinces except Saskatchewan, the return periods were slightly higher than for TXx, while for Oregon and Washington state, they were slightly lower. For TX7x, the return periods in all regions except Oregon were approximately a factor of two lower than those of TXx and TX3x. In Oregon, the return period is almost 20 times lower than that of TXx and 8 times lower than TX3x, 8 (CI: 4–36) years.

The reason why the return period in Oregon for TX7x is so much lower than for the other regions is the inclusion of 2022 data into our analysis. In late July 2022, Oregon experienced a long heatwave, and although individual daily temperatures in 2022 did not reach 2021

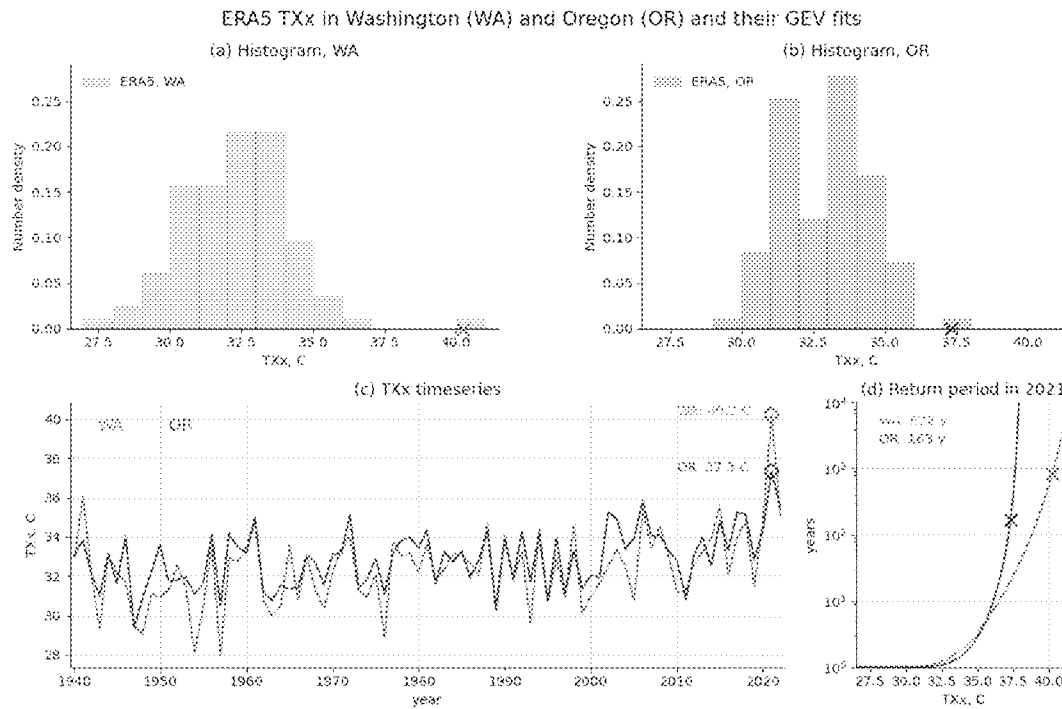


Fig. 4. ERA5 histograms (panels (a)–(b)), timeseries (panel (c)) and return period curves (panel (d)) shown in orange for Washington (WA) and in blue for Oregon (OR). The 2021 values are shown with crosses (panels (a)–(b), d)) or circles (panel (c)).

maxima, the high temperatures persisted longer, resulting in a 2022 TX7x being 0.5 °C warmer than that in 2021. At the same time, 2021 still holds the record for TXx and TX3x.

3.2. Sensitivity to the inclusion of 1940s ERA5 data

An important question, which arises looking at our estimations of return periods for the 2021 event is why the TXx return period values for BC are so much lower than for Washington and the rectangular regions used in previous studies. The main reason for the observed differences is the inclusion of the 1940–1949 period in our analysis. As shown in Fig. 3, 1941 was a year with another historic maximum in Western Canada, and although TXx was generally not as high as in 2021, taking into consideration lower GSAT in 1941, the influence on the 2021 return period estimation is noticeable. For example, the return period of the 2021 heatwave for BC TXx calculated using data from only the 1950–2021 period is 1152 (CI: > 126) years, which is more comparable with the return period for Washington based on 1940–2022 timeseries. As already noted, 1941 was not as extreme in Washington and Oregon, thus the inclusion of 1940–1949 data does not have a large effect on return periods for these states. The return period values for all regions and all variables based on 1950–2021 period can be found in Table S1 and fitted GEV parameters in Table S2. Furthermore, if considering timeseries from 1942 onward the return periods in all regions are virtually the same as if considering timeseries starting in 1950. This indicates that the 1941 event was predominantly responsible for the change in the return periods.

We also applied our analysis to the rectangular region defined by Philip *et al.* (2022), referred to hereafter as the WWA (World Weather Attribution) region. For the 1940–2022 data, the TXx return period yields 775 (CI: > 118) years, whereas for the 1950–2021 period, the same as considered by the authors of the study, it is 1217 (CI: > 136) years, consistent with their result. While the TXx return period for the WWA region is similar to that for Washington State, it is substantially higher than the return period for British Columbia. Furthermore, applying a similar analysis as in Section 3.1 to the 1941 event in British Columbia (using 1941 GSAT), we found TXx, TX3x and TX7x return

periods higher than those in 2021, of 735 (CI: > 135), 589 (CI: > 114) and 355 (CI: > 85) years respectively. Although the yearly maxima values for 1941 anomalies were slightly lower, so was the GSAT for 1941, resulting in higher return periods.

One could raise a legitimate concern in the quality of 1940–1949 data from ERA5, arguing that the dataset is fairly recent and for the preliminary version for the 1950s some issues were reported (Bell *et al.*, 2023). To validate the existence of the 1941 heat wave, we considered three sources of information. First, we analysed data from the Western Canadian weather stations available from the Adjusted and Homogenized Canadian Climate Data (AHCCD) (Vincent *et al.*, 2020). In total, the data from 111 stations covering both 1941 and 2021 heatwaves is available in British Columbia, Alberta and Saskatchewan. Example TXx timeseries for three stations in each of these provinces are presented in Fig. 5 with grey lines. It is obvious from Fig. 5 that for these nine stations, 1941 was an extreme year, with TXx comparable in magnitude with 2021 value. Similar results were obtained for the majority of other stations not shown here.

Second, we examined the year of the absolute maximum of TXx in the HadEX3 dataset (Dunn *et al.*, 2020). Since HadEX3 contains gridded TXx values from 1901 to 2018, we could not calculate regional averages the same way as we did for ERA5, however determining the year of the absolute TXx maximum can provide a quality check. HadEX3 data shows that for most of British Columbia, as well as for northern Saskatchewan and Alberta, 1941 was the year of the highest observed TXx (Fig. S2).

Lastly, we considered the records from the local newspapers. In the issues of the Victoria Daily Times from 15th to 30th of July, one can find reports of an “unprecedented heat wave”, “heat-related deaths” and the fact that the temperatures beat previous records from 1924 (The Victoria Daily Times, 1941a,b). While those statements cover mostly Vancouver and Vancouver Island, they still give an insight that 1941 was an extraordinary year. One can also find reports of the record temperatures in Alberta and Saskatchewan in the middle of July 1941 (The Victoria Daily Times, 1941c). Thus all three data sources support the ERA5 result that 1941 saw an exceptional heatwave in Western Canada.

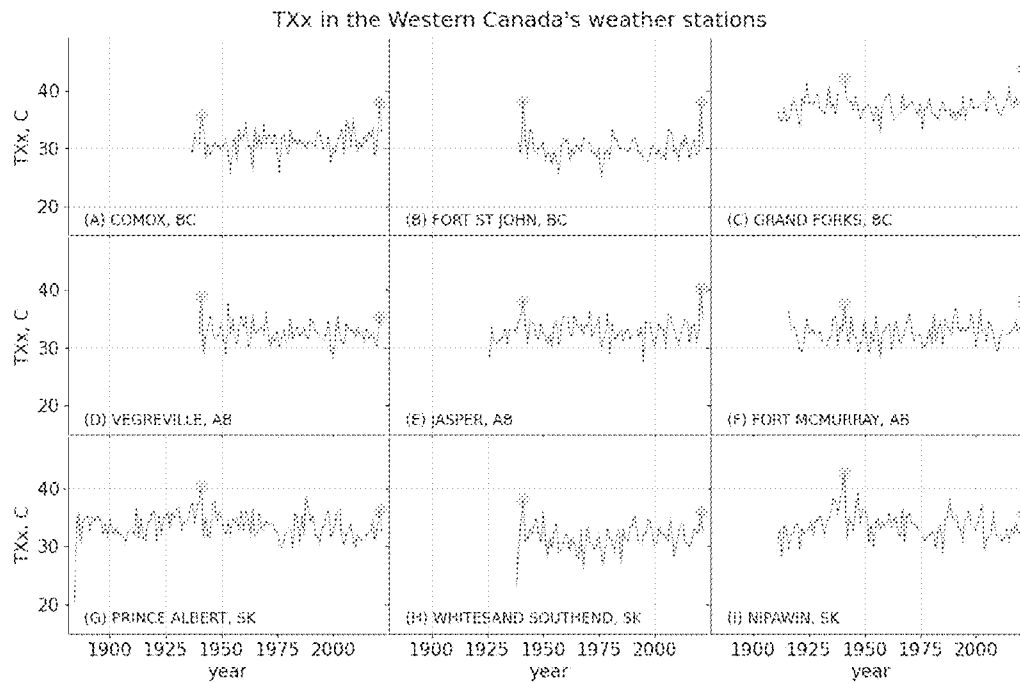


Fig. 5. TXx in Western Canadian weather stations based on the AHCCD record. Yellow circles show 2021 values and blue circles represent 1941 values.

Our findings emphasize the uncertainties associated with the calculation of return periods of several hundreds years based on 70–80 years of data. In particular, using only the data after 1950 we would infer that the 2021 event was a 1 in 1200-yr event in British Columbia, whereas an apparently even rarer event occurred in 1941, only 80 years ago. Or over Saskatchewan, we would infer that the 2021 event was a 1 in 100 year event using data since 1950, while a heatwave which was even hotter in absolute terms occurred in 1941. One cannot calculate with a high degree of certainty return periods exceeding several times the length of available observations in the area. Our results highlight the importance of considering as long as possible timeseries for the GEV fit and return period estimates. Inclusion even of one additional point can change the results drastically and it is in particular important for the events that exceed generational memory. As Philip et al. (2022) state, more studies are needed to understand the GEV analysis on annual maxima with short records and very extreme values, while Zeder et al. (2023) highlight the importance of communication of the uncertainty intervals on the return period estimates from the short observational records.

4. Evaluation of variability in maximum temperatures in CMIP6 data

Before using the CMIP6 data for attribution it is necessary to evaluate the quality of internal variability in maximum temperatures relative to the reanalysis. We used daily maximum air temperature data from 161 simulations from 22 models from the Coupled Model Intercomparison Project Phase 6 (CMIP6) (Eyring et al., 2016). We used data from the CMIP6 historical experiment (1940–2014) combined with SSP2-4.5 scenario (2015–2022) (O'Neill et al., 2016). All available simulations, except those with existing formatting issues, mismatched calendars, and those with reported *tasmax* variable errors were used in the analysis. For each time period, CMIP6 data were regridded onto an $0.5^\circ \times 0.5^\circ$ grid. Then, area averaged daily maximum air temperature (T_{max}) was calculated for each region. For TXx, the annual maxima of T_{max} were calculated, while for TX3x and TX7x the annual maxima

of the running T_{max} means over three and seven days respectively were calculated. For each variable and individual simulation, anomalies relative to 1940–1959 were obtained. We use 1940–1959 as a reference because it is the earliest available 20-yr period in ERA5 data and thus is closest to the preindustrial climate.

We analysed the standard deviations of TXx anomalies in ERA5 and in individual CMIP6 simulations for 1940–2022. In Fig. 6 we show only the values for TXx in British Columbia (panel (a)) and Saskatchewan (panel (b)) as the most extreme cases. The results for the other regions can be found in Fig. S3. It is clearly apparent that the standard deviation of TXx in British Columbia is much higher in ERA5 than almost all CMIP6 simulations (Fig. 6(a)). By contrast, in Saskatchewan the ERA5 standard deviation is smaller than the standard deviations in most CMIP6 models (Fig. 6(b)). That indicates that model variability in British Columbia is much smaller than the variability in the reanalysis data, while in Saskatchewan the model variability for most simulations is larger than the ERA5 variability. The same is true for TX3x and TX7x. Moreover, British Columbia is the only region we considered where ERA5 variability is larger than the simulated one. For all other regions, CMIP6 variability is larger than that of ERA5, but the magnitude of the differences varies from region to region, with Oregon and Saskatchewan having the largest differences (see Fig. S3).

Consistent with these results, Fig. 7 shows the geographical pattern of the ratio of standard deviation of TXx in CMIP6 to ERA5, indicating that the models tend to underestimate the variability relative to ERA5 over the oceans and many coastal regions, while they tend to overestimate the variability in the continental interior of North America. At the same time, for British Columbia, in addition to the coast, for the most of the interior part of the province (with exception of Kootenay region) the variability is underestimated. Since there is no obvious indicator (e.g., topography), why the TXx variability in British Columbia is lower, that question is deferred to the future studies. However, Fig. 6 indicates that this result is systematic across the CMIP6 models, and is not driven by one or two outliers.

To better compare the variability in TXx in ERA5 reanalysis and CMIP6 simulations, Fig. 8 compares TXx data from 1940 to 2022 from

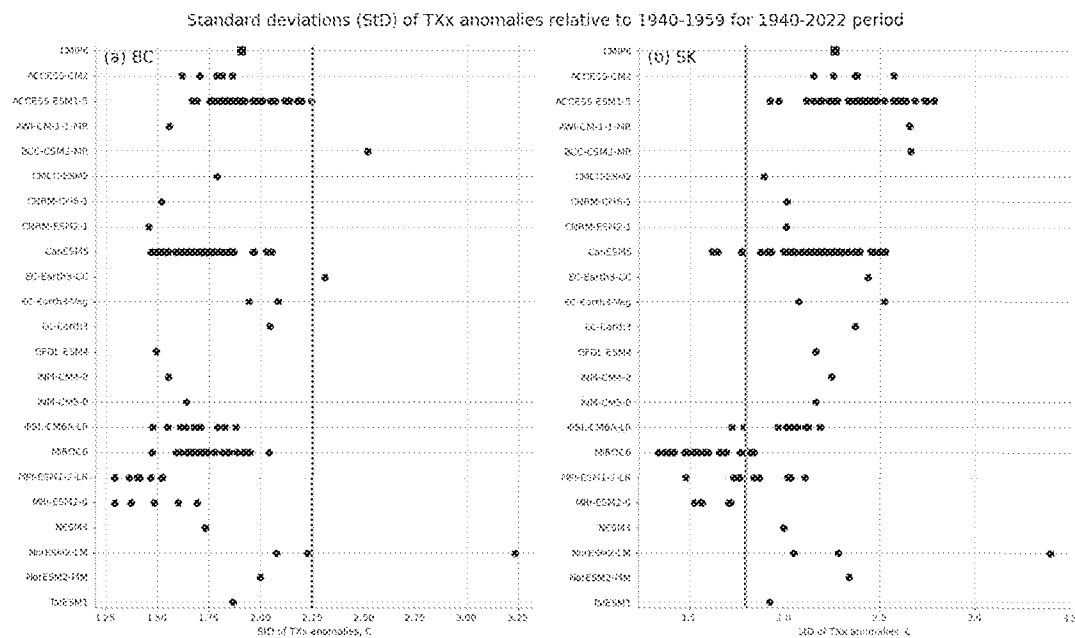


Fig. 6. Standard deviation (Std) of TXx anomalies in British Columbia (a) and Saskatchewan (b) in the 1940–2022 period. The circles represent the values for individual model realizations, the square shows a CMIP6 multi-model value weighted by the number of realizations in the model ensemble. The red vertical line depicts the ERA5 value.

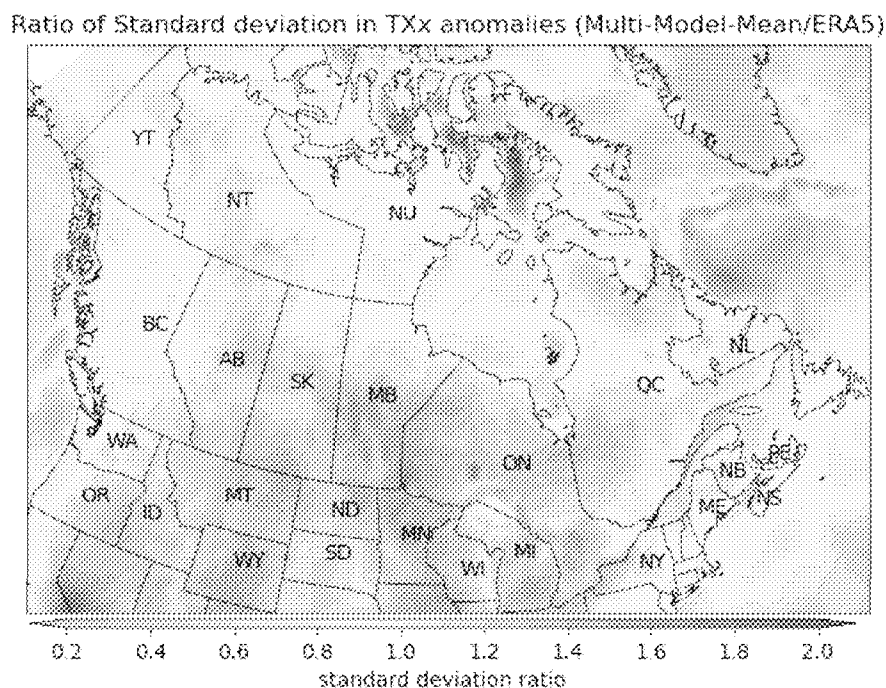


Fig. 7. Ratio of the TXx standard deviation in CMIP6 models to that in ERA5 for the period from 1940 to 2022.

ERA5 (red line) with the weighted CMIP6 multi-model mean (blue line) and the minimum and maximum across the CMIP6 ensemble (blue shading). One can see, that overall, in British Columbia (panel (a)), the ERA5 TXx anomalies span the range of CMIP6 anomalies and anomalies as large as those in 1941 and 2021 were only simulated just a few times. By contrast, in Saskatchewan (panel (b)), the CMIP6 the maximum and minimum borders are much higher/lower than the ERA5 data.

Figs. 6 and 8 indicate that for the period of interest, for British Columbia, CMIP6 models tend to underestimate TXx variability, making the probability of the 2021 event too low; for Saskatchewan the situation is the opposite, and simulated variability that is higher than observed values dominate the distribution making the simulated probability of the 2021 event too high. The differences in variability help explaining the differences in the reanalysis and CMIP6 return periods

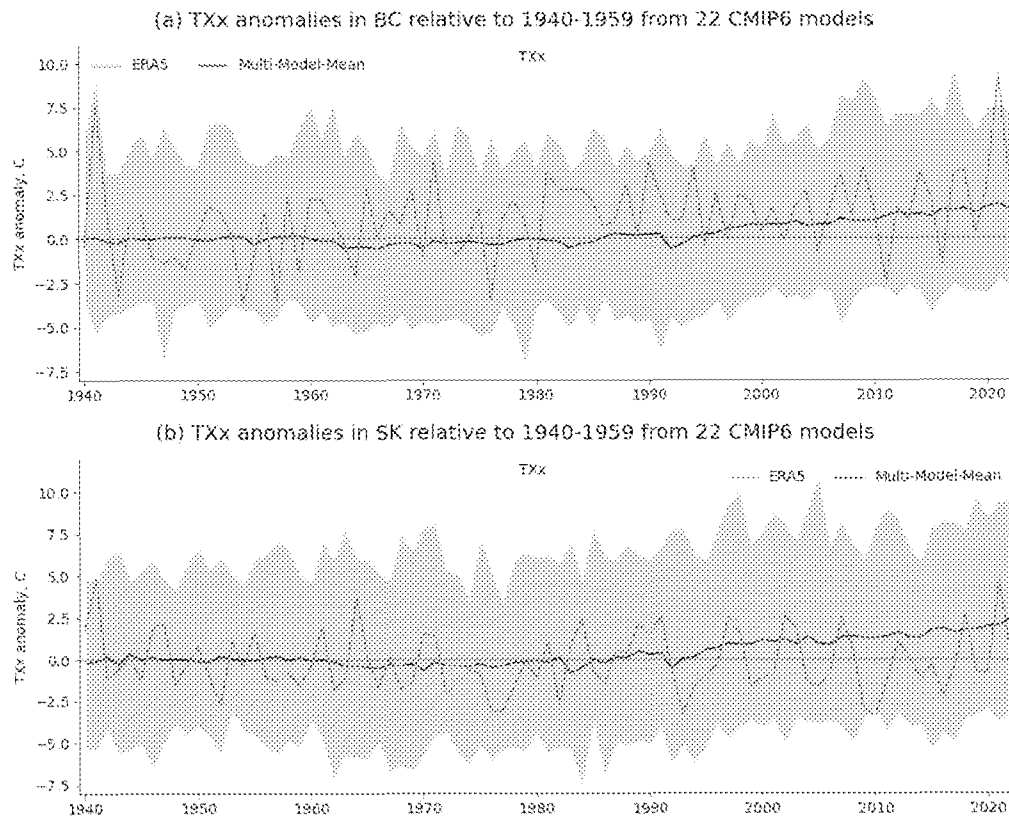


Fig. 8. TXx anomalies in BC (panel (a)) and SK (panel (b)) from 1940 to 2022 relative to 1940–1959 period. Red lines show the timeseries from ERA5, while the blue lines show the CMIP6 multi-model mean and the blue shows minimum and maximum in the multi-model ensemble.

outlined in Section 5. In particular, the modelled return periods in British Columbia are noticeably higher than those estimated from reanalysis, while in other provinces they are lower, with Saskatchewan being the most extreme case.

5. Attribution of the 2021 event

5.1. Data and method

To attribute an extreme event to climate change, the probabilities of an event in the factual (i.e. the current climate) and counterfactual (natural forcing only or pre-industrial climate) world (e.g. Allen and Stott, 2003; Seneviratne et al., 2021) are compared. For the factual world, we used a 20 year period centred at 2021 (2011–2030) from the concatenated historical and SSP2-4.5 scenario (O’Neill et al., 2016). Since, most of the simulations from the Detection and Attribution Model Intercomparison Project (DAMIP) (Gillett et al., 2016) end in 2020, we used data from the historical experiment over the quasi-preindustrial period of 1850–1900 as a counterfactual. To provide projections of the probability of a comparable event at the end of the 21st century, we used data for 2081–2100 from the SSP2-4.5 scenario. SSP2-4.5 is considered to be an “intermediate” scenario and is associated with 2.7 °C global near-surface air temperature (GSAT) warming in 2081–2100 relative to 1850–1900 (IPCC, 2021).

We fit stationary GEV distributions to the CMIP6 multi-model ensemble for each period and then calculate the return periods for an event of the same magnitude as the 2021 event in ERA5 anomalies (Table 2). A similar approach was used in attribution analysis of the maxima of two-day precipitation in British Columbia (Gillett et al., 2022). We choose to fit stationary distributions here because we focus on shorter time periods (51 and 20 years for the preindustrial and current and future climate respectively), where the climate change signal is relatively stable, unlike the 83 year period analysed in ERA5 data.

5.2. Event attribution of TXx in Alberta

The results of the TXx attribution analysis for Alberta are presented in Fig. 9. In this section we concentrate on Alberta rather than on British Columbia for two reasons: first, the return period of 2021 TXx was higher in Alberta, meaning that the 2021 heat wave was rarer in Alberta. Second, as shown in Section 4, the CMIP6 variability is closer to the observed in Alberta resulting in more robust estimates of the return periods.

In Fig. 9(a), histograms of TXx anomalies for the current climate (2011–2030) are shown in orange, for the quasi-preindustrial (1850–1900) in green, and for the future climate (2081–2100) in blue. The fitted GEV distributions are shown with solid lines in corresponding colours, with shaded areas depicting the 90% CIs obtained from bootstrap re-sampling. The goodness of the fit is illustrated by the Q–Q, or quantile–quantile, plot (Fig. 9(b)). Overall, the GEV distributions fit the simulated values very well.

In panel (a), one can see that in comparison to the green histogram, the orange histogram and GEV fit are shifted towards higher anomalies values indicating higher TXx in 2011–2030. The blue histogram is shifted even further to the right, meaning there is an even higher probability of larger TXx values by the end of the century under the SSP2-4.5 scenario. Based on the standard deviations of the fitted GEV functions, the 2011–2030 distribution is slightly wider than the 1850–1900 one and the 2081–2100 is wider still. The latter is visually noticeable in the figure as well. Several factors contribute to the widening of the distributions. First, differences in the equilibrium climate sensitivity of the CMIP6 models, and second a possible increase of the variability of the extremes in the warming climate (Seneviratne et al., 2021). Differences in warming rates between models represent real uncertainty in how the climate will respond under the SSP2-4.5 scenario, and hence this broadening of the distribution in panel (a) represents real uncertainty in how TXx is projected to change under this scenario. By

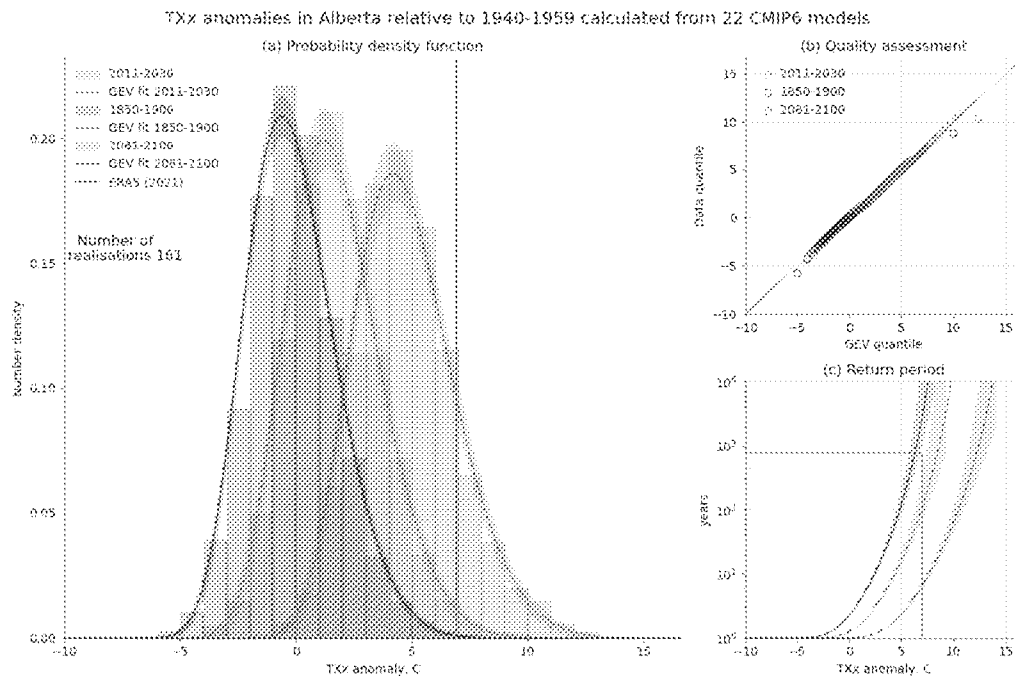


Fig. 9. TXx CMIP6 probability density function (panel (a)), QQ-plot (panel (b)) and return periods (panel (c)) for Alberta. The values corresponding to the quasi-preindustrial climate (1850–1900) are shown in green, for the current climate (2011–2030) in orange and for the 2081–2100 period under SSP2-4.5 scenario in blue. The shaded intervals in panels (a) and (c) show the 90% CIs obtained from bootstrap re-sampling. In panels (a) and (c), 2021 ERA5 TXx anomalies relative to 1940–1959 are shown with vertical red lines, and the ERA5 TXx return period is shown with the horizontal red line in panel (c).

carrying out our analysis in this way, rather than making it conditional on a particular change in global mean temperature, our return period and risk ratio estimates will reflect this uncertainty in the climate response.

Based on the GEV fits, we also assessed return periods of the 2021 event from CMIP6 models. Results are presented in Fig. 9(c) and Table 2. In Fig. 9(c), as for the other panels, the green colour corresponds to the quasi-preindustrial climate, the orange to the current climate and the blue one to the projections under the SSP2-4.5 scenario at the end of the 21st century. The solid lines show the return periods based on GEV fits and shaded regions show 90% CIs from the bootstrap re-sampling. The red lines show the TXx anomaly and the ERA5 assessed return period for the 2021 event.

Fig. 9(c) and Table 2 show that in the quasi-preindustrial climate TXx anomalies as high as observed in 2021 were extremely rare with an estimated return period of 2322 (CI: 889–22043) years, while the return period in the current climate based on CMIP6 data is 98 (CI: 62–286) years. We hence calculate a risk ratio of 24 (CI: 5.6–217) for an event at least as strong as that observed in 2021 in Alberta (Table 3). The CMIP6 best estimate of the return period for the current climate is almost eight times smaller than that estimated from ERA5, although the CIs overlap. Under the SSP2-4.5 scenario, by the end of the 21st century, events comparable to the 2021 TXx in Alberta will become much more frequent, with an estimated return period of 1 in 6.2 (CI: 5.5–7.3) years, making it 16 (CI: > 9.9–45) times more likely relative to the current climate (see Table 3).

We also calculate the intensity of an event of the same return period as the 2021 TXx (a 1 in 769 years event based on ERA5) in CMIP6 ensemble. In the current climate, according to CMIP6 data, TXx anomalies of 8.5 (CI: 7.4–9.3) °C would have the same return period as the 2021 event in ERA5 data, whereas in the quasi-preindustrial climate anomalies of 6.3 (CI: 5.7–6.8) °C would be as rare. By the end of the century under the SSP2-4.5 scenario, the intensity of a comparable in rarity event would increase to 12.3 (CI: 11.4–13.2) °C in terms of anomalies. While the intensity of the 1 in 769 year TXx in the current climate in CMIP6 models is somewhat higher than the

observed 2021 value in ERA5, we have shown earlier that the best estimate of the return period from CMIP6 is lower than that from ERA5, resulting in an overestimation of the 1 in 769 years event intensity from CMIP6 data for the current climate. This could relate in part to uncertainty in the estimation of such long return periods from the short periods of observations (see Section 3.2) as well as higher than observed variability in CMIP6 data. While we are of the recent progress on correction for both of those factors (e.g. Salpratz et al., 2019; Miralles and Davison, 2023), we defer the implementation of those corrections to the future studies. Nevertheless, our results show that human induced climate change contributed substantially to the severity of the 2021 heat wave in Alberta.

5.2.1. Event attribution for other regions and for longer duration

We repeated the calculations of return periods and risk ratios for the other regions (British Columbia, Saskatchewan, Washington, Oregon) as well as for TX3x and TX7x. TXx return periods from ERA5 and CMIP6 for the 2021 event in the current climate generally exhibit overlapping CIs, except in Saskatchewan and Oregon (Table 2), where the CMIP6 return periods are significantly lower, which is explained by the overestimated variability in CMIP6 models in these regions (Section 4). While the CIs overlap, in British Columbia the central estimate of the return period is much higher based on CMIP6, which is due to the models underestimating the variability in this region (Table 2). For the WWA region, our calculated return period of 898 (CI: 342– 2×10^6) years for the current climate is very close to the 1000 year return period reported in Philip et al. (2022). Like them, we also find that the 2021 TXx value in this region was virtually impossible in 1850–1900 period. While our estimates for the return period for the end of the century are slightly higher, unlike Philip et al. (2022) we use a milder SSP2-4.5 scenario, which is associated with the lower GSAT warming.

Similar to ERA5, the TX3x return periods are of the same order of magnitude as TXx return periods, with the Canadian provinces having return periods for TX3x which are slightly higher than for TXx and the American states having return periods for TX3x which are slightly

Table 2

Return periods (RP) for TXx, TX3x and TX7x anomalies equal to those observed in 2021. CIs are shown in brackets. CIs beginning with > indicate an infinite upper bound.

Region	TXx return period, years (CI)			
	ERA5 (2021)	CMIP6		
	1940–2022	2011–2030	1850–1900	2081–2100
BC	236 (> 52)	7668 (> 1453)	∞ (> 3.5×10^7)	41 (31–84)
AB	769 (> 124)	98 (62–286)	2322 (889–22043)	6.2 (5.5–7.3)
SK	75 (32–966)	8.0 (6.9–9.5)	45 (37–69)	1.8 (1.7–1.9)
WA	822 (> 118)	208 (112–1095)	∞ (> 10^6)	12 (11–17)
OR	163 (> 35)	14 (12–21)	352 (224– 2×10^5)	2.7 (2.4–2.9)
WWA	775 (> 119)	898 (342– 2×10^6)	∞ (> 6×10^6)	33 (26–58)
Region	TX3x return period, years (CI)			
	ERA5 (2021)	CMIP6		
	1940–2022	2011–2030	1850–1900	2081–2100
BC	212 (> 50)	9814 (> 1598)	∞ (> 10^9)	41 (32–88)
AB	891 (> 128)	138 (82–554)	4056 (1442– 10^6)	7.0 (5.9–8.0)
SK	137 (> 45)	8.2 (7.1–9.8)	52 (41–78)	1.7 (1.6–1.8)
WA	527 (> 91)	157 (90–703)	∞ (2×10^5)	10 (9–13)
OR	63 (> 19)	13 (11–19)	331 (230–13352)	2.6 (2.3–2.7)
WWA	570 (> 96)	589 (252– 10^5)	∞ (> 10^6)	23 (19–40)
Region	TX7x return period, years (CI)			
	ERA5 (2021)	CMIP6		
	1940–2022	2011–2030	1850–1900	2081–2100
BC	155 (> 42)	948 (> 377)	4×10^9 (> 48666)	13 (11–18)
AB	500 (> 84)	46 (33–91)	1119 (533–4764)	3.4 (3.1–3.8)
SK	50 (21–893)	4.9 (4.4–5.6)	26 (22–34)	1.4 (1.3–1.4)
WA	153 (> 33)	35 (26–58)	3357 (1205– 5×10^6)	3.7 (3.3–4.1)
OR	8 (4–36)	4.8 (4.3–5.4)	96 (36–152)	1.5 (1.4–1.5)
WWA	289 (> 53)	112 (70–461)	10^5 (> 5900)	7.2 (6.2–8.4)

Table 3

Risk ratios (RR) for TXx, TX3x and TX7x anomalies at least as large as those observed in 2021, calculated from CMIP6 data.

Region	TXx risk ratios		
	2011–2030/ 1850–1900	2081–2100/ 1850–1900	2081–2100/ 2011–2030
BC	∞ (> 0.77)	∞ (> 7×10^5)	189 (> 29)
AB	24 (5.6–217)	374 (142–3492)	16 (9.9–45)
SK	5.7 (4.4–8.9)	26 (21–38)	4.5 (3.9–5.4)
WA	∞ (> 3625)	∞ (> 10^6)	17 (8.2–81)
OR	24 (16–1135)	130 (93–6430)	5.3 (4.6–7.6)
WWA	∞ (> 1601)	∞ (> 10^6)	27 (8.5–45911)
Region	TX3x risk ratios		
	2011–2030/ 1850–1900	2081–2100/ 1850–1900	2081–2100/ 2011–2030
BC	∞ (> 2.4)	∞ (> 2×10^6)	226 (> 31)
AB	30 (5.4–658)	597 (210–14051)	20 (12–81)
SK	6.4 (4.7–9.7)	30 (24–45)	4.7 (4.1–5.7)
WA	39 (> 1027)	∞ (> 20129)	15 (8.2–64)
OR	24 (16–946)	128 (92–5310)	5.3 (4.6–7.5)
WWA	∞ (> 710)	∞ (> 5×10^5)	25 (8.8–4289)
Region	TX7x risk ratios		
	2011–2030/ 1850–1900	2081–2100/ 1850–1900	2081–2100/ 2011–2030
BC	3×10^6 (>0.84)	3×10^7 (>3459)	71 (27– 4×10^{11})
AB	25 (8.8–103)	325 (154–1391)	13 (9.5–26)
SK	5.4 (4.3–7.1)	19 (16–25)	3.6 (3.2–4.1)
WA	96 (30– 10^5)	914 (330– 5×10^6)	9.5 (7.2–16)
OR	20 (7.4–31)	65 (25–105)	3.2 (2.9–3.7)
WWA	119 (> 30)	1856 (> 806)	16 (9.7–63)

lower. As for ERA5, the 2021 event was substantially less rare based on CMIP6 simulations of TX7x in all cases. Based on this analysis, for all regions except British Columbia the probability of an event like that in 2021 has increased at least four times in comparison to the preindustrial climate and will increase substantially more by the end of the century under the SSP2-4.5 scenario. For British Columbia, the lower end of the risk ratio CI was hard to constrain, due to the underestimation of variability in the CMIP6 models, and the finding of an infinite return period for the present day in many bootstrap samples.

Based on CMIP6 data for British Columbia and Washington the 2021 event was virtually impossible in the pre-industrial climate. For Oregon, 2021 TXx and TX3x values were also quite rare (1 in 350 years) on the pre-industrial climate, while the TX7x value was much more frequent (1 in 96 years event). At the same time for Saskatchewan, the best estimates of the return period for the pre-industrial climate are

even lower than the best estimates from ERA5 for the current climate. We attribute these discrepancies to the variability and urge excising caution when using CMIP6 data in particularly for British Columbia and Saskatchewan. We plan to address the issue of the unrealistic variability in the future studies.

6. Conclusions

While previous work on the 2021 Pacific Northwest heatwave has generally focused on a relatively small rectangular regions, in this paper we demonstrate that record temperatures associated with this heatwave were observed much more widely across the Pacific Northwest and Prairies. In particular, we demonstrated that the heat wave affected not only the southern part of British Columbia, but extended across almost the whole province, with June 29th temperatures extreme on the provincial scale, and a British Columbia-average TXx anomaly of 9.3 °C relative to a 1940–1959 reference period. Our analysis also demonstrated that regional temperature anomalies were extremely high in Alberta and Washington state. Saskatchewan and Oregon experienced temperature extremes during the 2021 heatwave as well, although anomalies were not as high as for the other regions. Using ERA5 data, the duration of the heatwave in each region was calculated, showing that in Saskatchewan, British Columbia, and Alberta the heatwave lasted six to eight days, while the heatwave in Washington and Oregon it was longer, twelve and thirteen days respectively.

Based on a non-stationary GEV distribution fit to the ERA5 time-series for the period from 1940 to 2022, TXx observed in British Columbia in 2021 was a 1 in 236 (CI: > 52) year event, making the probability of the event considerably higher than previously thought. The reason why our estimates differ from the previously reported return periods for similar regions is the inclusion of recently released ERA5 reanalysis data for the 1940s. That data covers a heatwave which occurred in 1941, which was not as hot in absolute terms, but which was a rarer event relative to the cooler climate of the time. The return periods for 2021 TXx in Washington and Alberta exceed 700 years, while in Saskatchewan and Oregon lower return periods were observed (75 and 163 years respectively). The results for TX3x showed return periods of the same order of magnitude, while for TX7x the return periods were about two to four times smaller.

Comparing the TXx, TX3x and TX7x variability between models and observations, we found that CMIP6 models tend to underestimate the

variability in British Columbia and overestimate it in other regions, in particular in Saskatchewan and Oregon. This results in overestimation of the 2021 return periods from CMIP6 data for British Columbia and unrealistic underestimation for Saskatchewan and Oregon. Based on the CMIP6 simulations we found that the probability of the 2021 event has already increased dramatically for TXx, TX3x and TX7x and is projected to increase much more by the end of the century under SSP2-4.5 scenario. Although differences between simulated and observed variability make it hard to robustly estimate risk ratios for some of the regions, we hope to address this issue in future work.

Overall, our results highlight how sensitive return period estimates are to the region and climatological timeseries choice. We show that inclusion of just an additional decade and in particular the hot extreme of 1941 in our analysis can drastically change the results, and thus it is important to consider as long timeseries as possible. Furthermore, our analysis shows that the choice of region can influence the return periods and attribution results. When considering British Columbia as a single region, a reasonable choice based on the distribution of 2021 temperature anomalies, one finds a much lower return period for the 2021 event than if considering the rectangular (Philip *et al.*, 2022) region containing part of British Columbia as well as parts of Washington and Oregon states, which was also justified. Thus, particularly in the context of climate change adaptation, one cannot safely extrapolate return periods from one region to another even if the regions overlap.

CRedit authorship contribution statement

Elizaveta Malinina: Conceptualization, Formal analysis, Investigation, Methodology, Software, Validation, Visualization, Writing – original draft. **Nathan P. Gillett:** Methodology, Supervision, Writing – review & editing, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

ERA5 data was downloaded from Copernicus Climate Change Service (C3S) Climate Data Store (CDS) (Hersbach *et al.*, 2020a) using `era5cli` software. CMIP6 data was obtained through ESGF nodes. Shape files for Canadian provinces were downloaded from Government of Canada (2016) and for the USA states from United States Census Bureau (2018). The AHCCD station data were obtained from ECCCdataportal. The CMIP6 data analysis was done by creating ESMValTool (Andela *et al.*, 2022; Righi *et al.*, 2023) recipes and corresponding diagnostics available at GitHub. The ClimextRemes package (Paciorek *et al.*, 2018) was used to fit GEV distributions. The same methods are planned to apply for analysis of other heatwaves in the future. The example for the recent 2023 spring heatwave in Alberta is shown in Supplements S7.

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Appendix A. Supplementary data

Supplementary material related to this article can be found online at <https://doi.org/10.1016/j.wace.2024.100642>.

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From: Ross McKittrick [ross.mckittrick@gmail.com]
Sent: 8/15/2025 3:00:15 PM
To: John Christy [climateman60@gmail.com]
CC: Steven Koonin [steven.koonin@gmail.com]; Judith Curry [curry.judith@gmail.com]; Roy Spencer [roywspencer@hotmail.com]
Subject: Re: NCA5

Ah. I can see why people are getting worked up. What he said was "updated reports ON those and with comments ON those." I suspect many people heard "updated reports" and stopped listening at that point. We do need to get back to the NCA5 report when we can, once we have guidance from the suits about what we're able or not able to discuss.

On Fri, Aug 15, 2025 at 10:52 AM John Christy <climateman60@gmail.com> wrote:
From The Hill

Energy Secretary Chris Wright indicated this week that the Trump administration is reviewing and could seek to change past climate reports. Wright, in a Tuesday evening appearance on CNN's "The Source," was asked why the administration removed past versions of the National Climate Assessment from government websites.

"Because we're reviewing them," he replied, "and we will come out with updated reports on those and with comments on those."

When reached for comment, the Energy Department declined to provide more information on the review efforts. Instead, spokesperson Andrea Woods referred The Hill to remarks from Wright during the same interview.

"I don't know why they're taken down," Wright told host Kaitlan Collins. "They're easy to find anywhere. If anybody can't find the National Climate Assessment report, they just got to Google a little better."

Woods told CNN that Wright "was not suggesting he personally would be altering past reports." The 1990 Global Change Research Act requires the federal government to produce a report about climate change every four years.

Sign up for the Morning Report

On Fri, Aug 15, 2025 at 9:49 AM Steven Koonin <steven.koonin@gmail.com> wrote:
(Note dropping Jeremy from the cc list)

I think we should find some way to release our critique of NCA5, taking care to purge it of any recommendations. Could be an Appendix to the CWG final, since it's likely that more than a few comments will refer to it.

Steven E. Koonin

On Aug 15, 2025, at 07:43, John Christy <climateman60@gmail.com> wrote:

These were the Secretary's remarks about revisiting the NCA5. They were fairly vague.

John C.

On Fri, Aug 15, 2025 at 9:42 AM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

John can you ask them for details or sources of this news? I for one know nothing about any plans to create a revised version of NCA5.

On Fri, Aug 15, 2025 at 10:40 AM John Christy <climateman60@gmail.com> wrote:

As mentioned earlier, several folks on the State Climatologist listserve, who helped author NCA5, are consternating over a proposed modification of NCA5. As I understand it, we will offer a review of NCA5 but with legal issues now, are we being asked to make any recommendations? Will our review even be released (when we finalize it)?

John C.

From: Roy Spencer <roywspencer@hotmail.com>
Sent: Thursday, May 29, 2025 11:15 AM
To: Steven Koonin; 'John Christy'; 'Ross McKittrick'
Cc: 'Travis Fisher'; 'Judith Curry'; 'Josh Loucks'
Subject: Re: NCA5: Scientific assessment or social engineering?

I read some of the NAS review of NCA5 this morning... absolutely glowing praise. It applauded the inclusion of DEI and minorities-to-be-hardest-hit language.

It also says there are over 500 authors of NCA5, which includes racial balance as a criterion for inclusion.

I re-read the 1990 Act creating the USGCRP, and it only mentions an NRC review of the multi-agency research PLAN, not the NCAs. So, I assume the NAS review was just to add gravitas to the 500+ authors?

-Roy

From: Steven Koonin <steven.koonin@gmail.com>
Sent: Thursday, May 29, 2025 9:09 AM
To: 'John Christy' <climateman60@gmail.com>; 'Ross McKittrick' <ross.mckittrick@gmail.com>
Cc: 'Roy Spencer' <roywspencer@hotmail.com>; 'Travis Fisher' <travis.scott.fisher@gmail.com>; 'Judith Curry' <curry.judith@gmail.com>; 'Josh Loucks' <loucksj14@gmail.com>
Subject: RE: NCA5: Scientific assessment or social engineering?

I've downloaded the report (<https://nca2023.globalchange.gov/downloads/>) There's very little of the foundational science in its 1834 pages(!) that's amenable to serious scientific critique.

I also attach the NASEM review of the NCA5 draft, as well as the authors' responses to that review.

And here's a link to the "gold standard" EO: <https://www.whitehouse.gov/presidential-actions/2025/05/restoring-gold-standard-science/> . A reminder that its criteria are:

- (i) reproducible;
- (ii) transparent;
- (iii) communicative of error and uncertainty;
- (iv) collaborative and interdisciplinary;
- (v) skeptical of its findings and assumptions;
- (vi) structured for falsifiability of hypotheses;
- (vii) subject to unbiased peer review;
- (viii) accepting of negative results as positive outcomes; and
- (ix) without conflicts of interest.

SEK

From: John Christy <climateman60@gmail.com>
Sent: Thursday, May 29, 2025 9:58 AM
To: Ross McKittrick <ross.mckittrick@gmail.com>
Cc: Roy Spencer <roywspencer@hotmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>; Steven Koonin

<steven.koonin@gmail.com>; Judith Curry <curry.judith@gmail.com>; Josh Loucks <loucksj14@gmail.com>

Subject: Re: NCA5: Scientific assessment or social engineering?

This mirrors the word usage from the briefing we received from the head of NCA5.

John C.

On Thu, May 29, 2025 at 8:56 AM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

I guess people used to the NCA genre are going to find our report totally off-topic.

On Thu, May 29, 2025 at 7:01 AM Roy Spencer <roywspencer@hotmail.com> wrote:

I did keyword counts in NCA5, and got the following results:

Mentions of RCP/SSP Scenarios (other than definitions):

RCP8.5/SSP5-8.5: 105 (53%)

RCP6.0/SSP3-7.0: 8 (4%)

RCP4.5/SSP2-4.5: 66 (33%)

RCP2.6/SSP1-2.6: 19 (10%)

Social/Societal keywords

Indigenous/Tribes/Tribal: 1,679

Culture/Culturally: 854

Equity/Equitable: 572

Sustainable: 295

Inequality/Unequal: 201

Racism/Racial: 153

Low-Income: 105

Injustice: 94

Communities of Color: 67

Minorities: 37

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Chapter 10 RISK AND ITS ASSESSMENT

“[I]n itself, nothing is a risk, there are no risks in reality. Inversely, anything can be a risk; it all depends on how one frames the danger, considers the event.” – French philosopher François Ewald¹

The concept of risk is an outgrowth of concerns about coping with dangers. For most of human history, the assessment and management of risk occurred informally by trial and error. More than 2400 years ago, Athenians articulated the capacity of assessing risk before making decisions.² However, as the influence and scale of technology expanded, it became evident that society needed to assess risks proactively. Science has increasingly allowed us to recognize and measure more subtle hazards, which has been coupled with a general decreasing tolerance for risk in modern industrialized society.³

Risk assessment and management as a scientific field is only about 30–40 years old. There are many different perspectives on risk, and some of these perspectives represent substantially different frameworks. However, there is broad agreement on the basic ideas and principles of risk understanding, assessment, communication and management.⁴

Risk may have positive or negative outcomes or may simply result in uncertainty. Fire and accidents only have negative outcomes, and they are often referred to as hazard risks. Taking a risk can also result in a positive outcome. Risk can also be related to uncertainty of outcome. However, most applications of risk analysis focus on adverse outcomes.

Climate change presents a challenge to risk assessment that is uniquely complex, uncertain and ambiguous. This chapter provides perspectives on risk and its perception, how risk is

characterized and analyzed, and why climate change is such a challenging problem for risk analysis.

10.1 Risk and Perception

“You are so convinced that you believe only what you believe that you believe, that you remain utterly blind to what you *really* believe without believing you believe it.”

– American writer Orson Scott Card⁵

Climate risk is generally regarded as hazard risk, although there are potential positive outcomes as well. The related terms “threat” and “hazard” refer to something that could cause harm, with the possibility of trouble, danger or ruin.⁶ The hazard may be something that is impending and imminent, or something that is likely, or merely possible. A forecasted extreme weather event is an imminent, impending hazard. For climate change supported by scenarios from global climate models or expert assessments, *likely* is the descriptor in IPCC parlance. Possibility is used for military threats and threats to cybersecurity, based on creatively imagined scenarios.

Risk has often been characterized as some type of statistical expected value – the product of the likelihood of occurrence and the impact if it occurs. However, such a characterization is appropriate only for simple or tame problems. Broader definitions of risk integrate specified consequences of an event or actions, a measure of uncertainty associated with the consequences, and the strength of the background knowledge that supports the assessment.⁷

The IPCC defines climate change risk through the dynamic association of the three core elements of risk: hazard, exposure and vulnerability. Hazard captures the frequency and intensity of extreme weather and climate events or slowly emerging change such as sea level rise. Exposure

refers to the elements of populace, infrastructures and social welfare at risk. Vulnerability refers to the exposures' potential to suffer as well as its ability to manage, withstand and rebound.⁸

The main concerns surrounding the consequences of manmade global warming are described below:⁹

- 1) Risk of death, injury, ill health or disrupted livelihoods in low lying coastal zones and small island developing states due to storm surges, coastal flooding and sea level rise;
- 2) Risk of severe ill health and disrupted livelihoods for large urban populations due to inland flooding;
- 3) System risks due to extreme weather events leading to breakdown of infrastructure networks and critical services such as electricity, water supply and health and emergency services;
- 4) Risk of mortality and morbidity during periods of extreme heat, particularly for vulnerable urban populations and those working outdoors in urban or rural areas;
- 5) Risk of food insecurity and the breakdown of food systems linked to warming drought flooding and precipitation variability and extremes, particularly for poorer populations in urban and rural settings;
- 6) Risk of loss of rural livelihoods and income due to insufficient access to drinking and irrigation water and reduced agricultural productivity, particularly for farmers and pastoralists with minimal capital in semi-arid regions;
- 7) Risk of loss of marine and coastal ecosystems, biodiversity and ecosystem goods, functions and services they provide for coastal livelihoods, especially for fishing communities in the tropics and the Arctic; and

- 8) Risk of loss of terrestrial and inland water ecosystems, biodiversity and the ecosystem goods, functions and services they provide for livelihoods.

As evidenced from this list, risks from human-caused climate change are convoluted with natural weather and climate variability, and are dominated by societal vulnerabilities in context of developing states and poorer populations.

10.1.1 Risk perceptions

“Something frightening poses a perceived risk. Something dangerous poses a real risk.” – Swedish physician Hans Rosling et al.¹⁰

Apart from the objective facts about a risk, the social sciences find that our interpretation of those facts is ultimately subjective. Risk science makes a clear distinction between professional judgments about risk versus the public perception of risk. Risk perception is a person’s subjective judgement or appraisal of risk, which can involve social, cultural and psychological factors.

No matter how strongly we feel about our perceptions of risk, we often get risk wrong. People worry about some things more than the evidence warrants (e.g. vaccines, nuclear radiation, genetically modified food), and less about other threats than the evidence warrants (e.g., obesity, using mobile phones while driving). This gap in risk perception produces social policies that protect us more from what we are afraid of than from what actually threatens us the most. Understanding the psychology of risk perception is important for rationally managing the risks that arise when our subjective risk perception system gets things dangerously wrong.¹¹

The Psychometric Paradigm research of psychologist Paul Slovic and collaborators describes a suite of psychological characteristics that make risks feel more or less frightening, relative to the actual facts^{12 13 14}

- natural versus manmade risks
- risks that are detectable versus undetectable (without special instrumentation)
- controllable versus uncontrollable risks
- voluntary versus imposed risks
- risks with benefits versus uncompensated risks
- known risks versus vague risks
- risks central to people's everyday lives versus uncommon risks
- future versus immediate risks
- equitable versus asymmetric distribution of risks.

In each of these pairs, the first risk type is generally preferred to the second risk type. For example, risks that are common, self-controlled and voluntary, such as driving, generate the least public apprehension. Risks that are rare and imposed that lack potential upside, like terrorism, invoke the most dread.¹⁵

Communicators hoping to spur action on climate change emphasize the manmade aspects of climate change, the unfair burden of risks on undeveloped countries and poor people, and the more immediate risks of severe weather events. The recent occurrence of infrequent events (e.g. a hurricane or flood) produces disparate perceptions of the risk of low probability events, that translate into perceptions of overall climate change risk.

The cultural theory of risk proposes that individual views on risk are filtered through cultural world views about how society should operate.¹⁶ People tend to relate their position on the environmental risk spectrum with how they perceive nature. Risk seekers view nature as robust, while risk avoiders see nature as fragile. In between can be found risk regulators that see a robust nature with bounds, leaving those who are indifferent to risk who view nature as unpredictable and view risk truly as just chance.¹⁷

Even if the initial harm is small, the social risk may be greatly amplified by the collective response or irrational behaviors of individuals. The response to climate risk, driven by alarmism and “extinction” rhetoric, has arguably crossed the threshold to actually increasing the social risk associated with climate change.

10.1.2 Risk characterization

“We must see these things objectively, as we do a tree; and understand that they exist whether we like them or not. We must not try and turn them into something different by the mere exercise of our own minds, as if we were witches.” – English writer and theologian G.K. Chesterton¹⁸

The concept of hazard risk captures both the threat contribution and vulnerability to the threat. Risk can be split into two main components: i) occurrence of the triggering events and associated uncertainties; and ii) consequences, given the events, and the associated uncertainties.

The concept of resilience is closely related to vulnerability. Resilience is defined as the ability of the system to maintain functionality and recover, given that one or more triggering events occur.

The ability—or lack of ability—of impacted systems to maintain performance and recover from the event will determine the consequences of the event.

An important element of characterizing risk is evaluating the strength of knowledge (Section 9.3). Concerns about strength of the knowledge base are raised by people questioning aspects of the IPCC's assessment that are used to infer climate risk. The IPCC approach is based on judgement of the available evidence and agreement among experts. More sophisticated knowledge characterizations for risk management include:¹⁹

- (i) the degree to which the assumptions made are reasonable/realistic based on our background knowledge – growing concern about the focus on implausible emissions scenarios RCP8.5/SSP5-8.5 (Section 7.1)
- (ii) the degree to which data/information exists and are reliable and relevant – the historical and paleo data base is inadequate for a complete characterization of natural climate variability on multi-decadal to millennial time scales
- (iii) the degree to which there is disagreement among experts (including those from different environments) – attempts to suppress disagreement and alternative perspectives among experts (Section 2.4)
- (iv) the degree to which the phenomena involved are understood and accurate models exist – concerns about the fidelity and utility of climate models (Chapter 6)
- (v) the degree to which the knowledge has been thoroughly examined with respect to unknown knowns – neglect of the unknown knowns associated with natural climate variability (Section 8.2).

Accepting the IPCC's assessments as the best available knowledge base is not inconsistent with acknowledging significant weaknesses in the knowledge base in context of climate risk analysis.

There are various types of risk, independent of the nature of the triggering event or the consequence. In 1921, economist Frank Knight articulated a definition of risk that distinguished risk from uncertainty.²⁰ Knightian risk implies that robust probability information is available about future outcomes, allowing risks to be treated in terms of probability and effects. Knightian risk underlies the technocratic, decisionistic and economic models of risk assessment and management.²¹ Similarly, mathematician Benoit Mandelbrodt differentiates between “mild” and “wild” risk.²² Systems that are predictable, have large quantities of sample cases to explore and that conform to normal style distributions would be considered mild. In contrast, random behavior, unusual distributions and largely unpredictable systems fall into the wild realm.²³ The danger lies in making the assumption a risk is mild when it is indeed wild.

Knightian-based, or mild, risk assessment and management is suited to simple, or tame, problems (Section 3.4). For simple risks, the cause for the risk is well known, the negative consequences are obvious, and randomness is low. The risk consequences are reversible and are well understood in terms of the science and regulation. Simple risks are recurrent and not affected by ongoing or expected major changes; hence, assessing the risks in statistical terms is meaningful. Examples include car accidents and regularly recurring weather hazards – hazards that insurance companies have traditionally covered.

Simple risks are characterized by low complexity, low uncertainty and low ambiguity. However, the most worrisome risks are not associated with simple problems. Wild risks are associated with high uncertainty and even ignorance. Complexity gives rise to systemic risk. Related to the

term “mess” that was introduced in Section 3.4, “ambiguity” means that there are different legitimate viewpoints from which to evaluate whether there are, or could be, adverse effects and whether these risks are tolerable. Ambiguity results from divergent and contested perspectives on the justification, severity or wider meanings associated with a perceived threat.²⁴

Some example types of risk that are not simple:²⁵

- Combination of low probability with high extent of damage. This includes technological risks associated with nuclear power plants or dams.
- Disaster potential is high and relatively well known, but little is known about causal factors. Earthquakes and volcanoes are examples.
- Human interventions in the environment that cause wide-ranging, persistent and irreversible changes, which are discovered after the interventions. Examples include large infrastructure projects such as dams and river engineering.
- There is a considerable delay between the triggering event and the occurrence of damage. Fossil fuel emissions are an example.

Risk conceptions can also be usefully categorized based on future predictability – the extent to which historical records are useful in assessing the risk of a future outcome.²⁶ When there is a clear causal relationship, the past can be a very good predictor of the future. However when uncertainty prevails the past is not a good indicator of the future and unprecedented outcomes can occur.²⁷

The concept of emerging risk is gaining increasing attention. Emerging risk is related to an activity when the background knowledge is weak but contains indications/justified beliefs that a new type of event could occur in the future and potentially have severe consequences to

something humans value. The weak background knowledge results in difficulty specifying consequences and as well in specifying scenarios.²⁸ Intergenerational impacts are a concern with emerging risks. Global warming is clearly an emerging risk. An important consideration when thinking about emerging risks is the speed at which they can become significant, which is referred to as the risk velocity.

Climate change risk includes elements of both incremental risk and emergency risk. Incremental risk displays creeping characteristics and the “fat tail” effect. Since changes take place rather slowly, the adverse consequences take a long time to emerge. Some climate impacts are expected to accumulate and worsen over time and across space. The slow creep of sea level rise is an example of incremental risk. A more complex example is the risk of long-term water shortage in Africa, which reduces food production over time and aggravates malnutrition and other health problems, leading to migration and regional violent conflicts. The potential impacts and long-term consequences can easily be underestimated in the early stage. Once incremental risks cross a critical point, they are difficult to manage – this relates to the so-called climate “tipping points” (Section 1.3.2).

Emergency risks are associated with extreme weather events; technically these are weather risks and not climate risks, even if global warming could be shown to incrementally worsen the weather hazard. Weather risk can become climate risk if global warming causes the event to exceed a vulnerability threshold that otherwise wouldn’t have been exceeded by the weather event. Attempts are also made to assess incremental costs/damages associated with extreme weather events. Such assessments are very challenging to make against the background of natural weather and climate variability.

10.1.3 Direct versus systemic risk

“A dike ten thousand feet long begins its crumbling with holes made by ants” –

Chinese philosopher (Zhou Dynasty) Han Fei Tzu²⁹

Direct risks from a hazard arise from a direct impact arising from the driver or event. Examples of direct risk from climate change include: heat stress to people, crop production failures, damage from unusual river flooding, sea level rise for coastal cities. Direct risks can be non-linear – while average conditions may change gradually, the risks can increase more rapidly if critical vulnerability thresholds are exceeded.

The risks of climate change to human interests depend not only on the direct impacts from changes in the physical climate, but also on the response of complex human systems such as the global economy, food markets, and the system of international security. In complex systems, small changes can sometimes lead to large divergences in future state. Systemic risks are characterized by a high degree of complexity, uncertainty, and ambiguity.³⁰ Many problems categorized as a “wicked mess” (Section 3.4) can also be categorized as systemic risks.

The greatest risks associated with climate change are systemic. Systemic risks may arise from the interaction of the climate with complex human systems such as global food markets, governance arrangements and international security. Systemic risks are much less straightforward to assess than direct risks. Systemic risks may be initiated by local stressor such as an extreme weather event, which can have impacts extending far beyond the impacted location. An example of national and international security systemic risk is triggered by regional drought, resulting in migration and displacement, food price spikes, civil unrest, state failure, terrorism, humanitarian crises, and transboundary water disputes.³¹

Hazard events that previously might have caused localized impacts can now have cascading and even global impacts. Consider the severe, widespread flooding in Thailand during 2011. The flooding was triggered by the landfall of a tropical storm, spreading through much of Thailand along the Mekong and Chao Phraya River basins. The systemic nature of this event arose from flooding of the industrial estates and production plants around Bangkok.³²

Apart from cascading effects on Thailand's economy, this local flood ended up having systemic impacts across countries, regions and economic sectors, affecting supply chains as far away as Japan and the United States. Key manufacturing sectors such as the automobile, electronics and electrical appliances industries experienced abrupt declines in production and exports. The disruption caused a global shortage of hard disk drives, which lasted throughout 2012.³³ Components manufactured in Thailand were essential for products finalized in other countries, causing disruption or collapse of the entire production chains.

10.2 Risk Assessment

“When knowledge is uncertain, experts should avoid pressures to simplify their advice.” – science and technology policy researcher Andy Stirling³⁴

Risk assessment is the systematic process of identifying risk sources, threats, hazards and opportunities; understanding how these can materialize/occur; identifying specific trigger events and event sequences, and what their consequences could be; representing and expressing uncertainties; and determining the significance of the risk.³⁵ The role of risk assessment is to support understanding, communication and decision-making processes.

Traditional risk assessment has been based on historic data—assessing probabilities of severity, frequency and impact based on experience from past events. In times of global change, this approach is no longer adequate to capture future risks. Scenarios of future climate and extreme events are generated by models and by storyline approaches (Chapters 7, 8, 9).

Apart from the likelihood and impacts of the risk, values and ancillary issues that contribute to risk perception should be integrated into the risk assessment. Further, risk evaluation requires assessment of risk(s)–benefit(s) and risk–risk trade-offs.³⁶ Risks need to be assessed in context of all of the relevant dimensions that matter to the affected populations.³⁷ A broad assessment of the risk provides a knowledge base so that decision makers have better guidance on how to select measures for managing the risk.

Narrow risk assessments of well-understood phenomena with ample data might be uncontested. However for contentious issues, the outcome of a risk assessment may be strongly influenced by the many inherent value judgments (often unknowingly) made by the analyst. Scientific studies have trouble resolving differences when the value assumption process is murky. Wise policymakers are likely to dismiss overly certain assessments, properly recognizing their biases or naivete. Trust is built via an open dialog around value assumptions, reducing the concerns of hidden agendas.³⁸

10.2.1 Acceptable versus intolerable risk

~~“We must contemplate some extremely unpleasant possibilities, just because we want to avoid them.”³⁹—American nuclear strategist Albert Wohlstetter~~

NEW QUOTE “Time heals nothing. It only brings other issues and tissues, and takes what is incurable or unacceptable out of the center of our attention.”

— **Ana Claudia Antunes, author of *The Tao of Physical and Spiritual***

An essential aim of risk assessment is to qualify the risks in terms of the social acceptability and tolerability. The “traffic light model” identifies three categories for risks: normal/acceptable risks, intermediate/tolerable risks and intolerable risks.⁴⁰ Normal risks are characterized by low complexity, little statistical uncertainty and low catastrophic potential (Knightian or mild risk), and are well understood by science and easily managed by regulatory mechanisms.⁴¹

Activities are tolerable if they are considered as worth pursuing for the associated benefits. For tolerable risks, efforts for risk reduction or coping are welcomed provided that the benefits of the activities are not lost. Burning fossil fuels has historically been considered a tolerable risk.⁴² Genuinely intolerable risks include existential threats—such as portrayed by the earth-impacting comet in the movie *Don’t Look Up*—or “ruin” problems.^{43 44}

How to draw the lines between “acceptable”, “tolerable” and “intolerable” is one of the most controversial tasks in the risk governance process for complex risks. Ambiguity results from divergent and contested perspectives on the justification, severity or wider meanings associated with a perceived threat.⁴⁵ Climate change risks have been characterized as acceptable, tolerable and intolerable by different individuals and constituencies – clearly an ambiguous situation.

Using the example of extreme weather risks, fairly routine destruction by hurricanes in certain coastal regions is generally categorized as tolerable, with some locations working to decrease vulnerability over time by improving building codes and engineering the coast to minimize the impact of storm surge. By contrast, a rare but extreme event such as Superstorm Sandy striking

New York City was judged to be associated with intolerable risk and a large adaptation deficit, given the large population and property value that was impacted and high vulnerability of the infrastructure.

For complex problems, often neither the risks nor the benefits can be clearly identified or agreed upon. Multiple dimensions and values need to be considered. A heavily contested assessment of the (in)tolerability or acceptability of risks is highly relevant input to the decision-making process, in context of the ambiguity of the risk.

10.2.2 Assessment of systemic risks

~~“We live on an island surrounded by a sea of ignorance. As our island of knowledge grows, so does the shore of our ignorance.”⁴⁶—John Wheeler~~

**NEW QUOTE “it is not a calculated risk if you haven’t calculated it.”
— Naved Abdali, author of Investor LINK**

In most problems of systemic risk, there are numerous ambiguous and unknown risks. Due to the complexity of systemic risk and the limited understanding of the risk propagation paths, there are substantial uncertainties in terms of the cascading effect of the systemic risk on the influence domain.

Key characteristics of systemic risk are broadly categorized under five themes: the scale of the system, the relationship of the elements within a system, the level of system understanding, the transboundary effects and the outcomes of systemic risk.⁴⁷

An important tool in characterizing systemic risk is forensic analysis of previous disasters. Forensic analysis combines retrospective longitudinal analysis, disaster scenarios, comparative case analysis and meta-analysis research, along with enhanced involvement of development stakeholders.⁴⁸ Forensic analysis can help better understand how and why disasters occur and their complex linkages with natural, infrastructure and societal systems.⁴⁹

Recognizing the depth of uncertainty about the future state of complex systems, assessment of systemic risk relies on the tools of scenarios and wargaming to help us think about what might happen. A key challenge for systemic risk assessment is to identify key linkages and the potential for critical transitions, in context of how systemic risks cascade through interdependent networks in both physical and social systems.⁵⁰ Complex challenges like pandemics or climate change should be assessed in the global context of megatrends such as urbanization, growing populations, demographic changes, environmental degradation, and technological change.

In risks that go beyond ordinary dimensions, such as COVID-19 and climate change, the reliability of any risk assessment is low, uncertainty is high, catastrophic potential can possibly reach alarming dimensions and systematic knowledge about the distribution of consequences is missing. Such risks may generate global, irreversible damages, which may accumulate during a long time or mobilize or frighten the population; or alternatively, the risks may turn out to be relatively benign. An unequivocal conclusion about the degree of validity associated with the scientific risk evaluation isn't feasible. For such problems, risk assessments are most effectively used as a tool used to represent and describe knowledge and lack of knowledge, and to formulate narratives of possible danger.

10.3 Climate Change Risk

“I have long argued climate messaging needs to be about here and now, kitchen table issues ... not 8 decades from now or way in the Arctic” – meteorologist Marshall Shepherd⁵¹

Many public organizations, ranging from the United Nations to local municipalities, have conducted risk assessments of climate change impacts. There is also a growing trend for private companies with responsibility to shareholders to conduct climate risk assessments. Virtually all of these climate risk assessments are based on assessment reports from the IPCC.

Cumulative risks at national and global levels are linked to the principle of avoiding dangerous climate change as defined by the UNFCCC, which is tied to assumed risk thresholds of +1.5 °C and +2 °C global warming above pre-industrial level. The most recent IPCC reports have formulated a risk-based approach for understanding the risk factors that lead to regional/local climate change impacts, and the role of adaptation initiatives in managing these risk factors. The importance of regional climate change risk assessments is recognized politically through the UNFCCC in context of Warsaw International Mechanism for Loss and Damage and the Sendai Framework for Disaster Risk Reduction under the auspices of the UN Office for Disaster Risk Reduction.^{52 53}

Thus far, government-sponsored climate change assessments have primarily been rooted in communicating a scientific consensus around anticipated changes in the physical climate system, along with some impacts that are generally implied by those climate changes. The assessments have not characterized or analyzed specific societal risks due to climate change, including socio-environmental causes of vulnerability related to climate hazards.⁵⁴

Climate risk assessments for industry sectors and infrastructure sectors reveal challenges from interconnectivities, interdependencies across value chains, and the impacts of policy and regulations.⁵⁵ International dimensions include mechanisms such as price, material flows, movement of people and political stability, with specific emphasis on food security and geopolitical risks.⁵⁶

The complexity, uncertainty and ambiguity associated with climate risk point to a number of challenges and frontier issues for assessing the risks associated with climate change in a policy-based context. These include the issue of dealing with systemic risks, critical knowledge gaps regarding Earth system processes, and the complexity of societal responses – which could collectively lead to extremely challenging outcomes. Much of the uncertainty in climate change assessments is irreducible; this uncertainty should be treated as a source of actionable knowledge through its influence on the viability of different decision strategies. While the UNFCCC has framed climate risk in terms of dangers, risk assessment should evaluate both positive and negative aspects of change to support a balanced appraisal of alternative decision options. Other issues relate to risk assessment processes themselves, such as managing uncertainty and clarifying the hidden values assumptions of the risk analysts.⁵⁷

This section presents the case that it is time for a shift in the objectives and implementation of climate change assessments – from making what amounts to a general case for ‘action’ regarding eliminating fossil fuel emissions, to characterizing specific regional risks and vulnerabilities in a manner that helps people develop, select, carry out, and monitor actions that ultimately have greater benefits than costs.⁵⁸

10.3.1 How we have mischaracterized climate risk

“The global climate change debate has gone badly wrong. Many mainstream environmentalists are arguing for the wrong actions and for the wrong reasons, and so long as they continue to do so they put all our futures in jeopardy.” – philosopher Thomas Wells⁵⁹

The communication and handling of the climate change risk is strongly dependent on the way risk is conceptualized and described.

In the early 1980’s, the United Nations Environmental Program (UNEP) became bullish on the idea that fossil fuels would produce dangerous climate change. The prospect of eliminating fossil fuels was congruent with UNEP’s broader interests in environmental quality and world governance. At Villach, Austria, in 1985 at the beginning of the climate treaty movement, the policy movement to eliminate fossil fuels became detached from its moorings in the science – the rhetoric of precaution argued that we should act anyway to eliminate fossil fuels, just in case.^{60 61} This perspective became codified by the 1992 UN Framework Convention on Climate Change (UNFCCC) Treaty in 1992, the Kyoto Protocol in 1997 and the 2015 Paris Climate Agreement.

The fundamental presupposition of the UNFCCC climate treaties and agreements is that human-caused climate change associated with fossil fuel emissions is dangerous – natural climate variability and most other human impacts on climate were essentially ignored. There was an implicit assumption that warming was dangerous, ignoring any potential benefits. In attempting to build political will for the international agreements, the adverse impacts of fossil-fuel driven climate change were exaggerated – more frequent and intense severe weather/climate events, sea

level rise and many adverse ecosystem, health, economic and geopolitical impacts, with all of their complex causes, were conflated with fossil-fuel driven warming (Section 1.1).

The torquing of climate science and the manufacture of a consensus around human-caused climate change (Chapter 2) not only oversimplified the scientific and social challenges, but led to the adoption of a “predict then act” strategy to manage and control the climate. This strategy is based on the belief that climate change is a simple or tame problem, with science trumping all practical questions and conflicting values and purposes.

One of the biggest problems associated with climate change assessments is that there is no simple way to articulate danger associated with a warmer climate (Section 1.3) To circumvent this challenge, the problem of climate change has been reduced to one of CO₂ emissions, with the elimination of human-caused emissions as the primary strategy for dealing with the problem. This strategy ignores the fact that there is no precise link between CO₂ emissions and global mean surface temperature, owing to uncertainties in climate sensitivity to CO₂ (Section 7.2) and the poorly constrained natural variations of the climate system. An alternative approach focused on a specified “dangerous” surface temperature threshold.⁶² This approach also requires accurate accounting and projections of natural climate variability from solar variability, volcanic eruptions, and multi-decadal to millennial scale ocean variations (Section 8.2). An additional complication is that the temperature targets of 1.5 and 2.0 °C do not have a sound scientific basis as thresholds for danger (Section 1.3).

Further, the temperature-based approach of specifying a dangerous threshold ignores nonlinearities in the climate system. Climatic “tipping points” (Section 1.3), which have been described as “real critical thresholds,” do not all occur at the same temperature threshold. If

unknown climate tipping points exist that are associated with natural climate processes, there can be no certainty that the risk of climate catastrophe would be eliminated even if emissions fell to zero.⁶³

The end result of the way in which the IPCC/UNFCCC have characterized the climate change problem is that we are focused on meeting emissions targets that are arguably unachievable in the near term, rather than on obtaining a deeper understanding of the climate system and the broader causes of vulnerabilities of human and natural systems. Further, the slow incremental risks of warming have been mischaracterized as urgent, leading to rapid implementation of policies that are not only costly and suboptimal, but also arguably reduce societal resilience to weather and climate variability, whatever their causes.

The politics of international climate governance has produced systematic biases in the kinds of expertise and evidence that are deemed appropriate for consideration.⁶⁴ The UNFCCC and IPCC have characterized climate change as an environmental and economic problem, and geoscientists and economists have dominated the assessment and policy making process.

However, the issues with increasing CO₂ and warming are social, not environmental. The Earth has undergone geological periods of higher temperatures and atmospheric CO₂ concentrations, during which life thrived. Characterization of climate change as an environmental problem has downplayed the cultural and political dimensions of the issue.⁶⁵ In fact, many social scientists have argued that climate change is a values problem, and that the disciplinary constrictions imposed by the IPCC and UNFCCC have neglected many important insights arising from a wide range of expert and unaccredited sources.⁶⁶

Clarifying the multitude of values in play would help illuminate the ambiguity surrounding interpretations of climate risk. However, characterizing climate change as a values problem can also lead into blind alleys. Many environmentalists have moralized the climate change problem as a simple, righteous values choice: Are you for the planet or against it?⁶⁷ This moralizing neglects to understand that people engage in activities which are of value to them that happen to emit carbon as a byproduct.⁶⁸ Further, this narrow moralizing systematically excludes important ethical values, such as improving the lives of the billion people presently living in unacceptable poverty or protecting other aspects of the environment.⁶⁹

The end result is that after 30 years of the UNFCCC/IPCC, we remain fixated on the minutiae of greenhouse gas emissions levels and the abstract and impossible problem of constraining atmospheric CO₂ concentration – while ignoring natural climate variability and drastically simplifying the human impacts and responses. As long as the current situation prevails, the IPCC’s assessments of anthropogenic climate change and the UNFCCC recommendations for action will remain seriously inadequate.

This fixation on global CO₂ levels alone as the problem and solution has led Norwegian risk scientist Terje Aven to conclude:

“The current thinking and approaches guiding this conceptualization and description have been shown to lack scientific rigour, the consequence being that climate change risk and uncertainties are poorly presented. The climate change field needs to strengthen its risk science basis, to improve the current situation.”⁷⁰

The UNFCCC is promoting a solution to an exceedingly complex, uncertain and ambiguous problem, without reference to wider ethical issues, and political and practical feasibility. We

have neglected to truly understand the problem and systematically and broadly evaluate the feasible policy space.

10.3.2 Reframing the assessment of climate risk

“[A] problem well put is half solved.” – American philosopher John Dewey⁷¹

Climate risks are exceedingly complex and scientific forecasts are subject to large uncertainties. As a result, there is deep uncertainty within climate change risk assessments. In the face of this deep uncertainty, a conventional predict-then-act approach is paralyzed by limits to prediction and lack of clarity regarding the potential consequences. Estimating the severity of the consequences based only on the potential economic losses ignores a series of impacts that are not easily quantified. In summary, we are far from a thorough assessment of full climate risk that would allow for efficient and targeted policies and support rational risk taking.⁷²

With this context, the risks from climate change need to be reframed more broadly, in context of advances in risk science.⁷³

There is an emerging literature on characterizing systemic risks from climate change. Systemic risks induced by climate change have three basic characteristics: 1) the wide scope of impacts, affecting a wide range of natural, economic and social systems; 2) the long duration of impacts; and 3) cumulativeness of these impacts that grow over time.⁷⁴

Assessment of systemic risk must account for the complexity of the climate system and the integrated effects on politics, the economy, society, culture, and the environment. Both emergency risks associated with extreme weather events and the slow creep of incremental risks have characteristics of systemic risk. Interaction of climate with a variety of processes of global

environmental change (both natural and human systems) represents an increased need to identify and characterize multiple stressors and their interactions across different scales.⁷⁵

How does a categorization of systemic risk actually help with the practical assessment of climate risk? Is such a diagnosis similar to a categorization of a problem as a wicked mess (Section 3.4), which may lead people to throw up their hands and shrug their shoulders? It is sometimes argued that a full assessment of the risks of climate change would be counterproductive, because the risks may be so large and the solutions so difficult that people will be overwhelmed with a feeling of helplessness, and will look the other way. However, rather than stymieing a solution, such categorizations help identify situations where simplistic solutions won't work and suggest paths that may lead to partial solutions and reductions in vulnerability.

There are a number of strategies that can be helpful for assessing systemic risks. These include portraying the full range of extreme future scenarios (global and regional), including extreme weather and climate events and worst-case scenarios (Chapters 8, 9). These scenarios can be used to drive narratives of danger and to stress test social and infrastructure systems. It is important to differentiate between acute impacts associated with extreme weather events versus incremental risks that develop over time, based on different latent periods and manifestations. Forensic analysis of previous disasters and their complex effects can provide important insights in developing scenarios of systemic risks.

Judgments of intolerable risks from climate change relate to mistakenly conflating the slow creep of global warming (an emerging risk) with consequences from extreme weather and climate events (emergency risks) and concerns about inequitable risk exposure to poorer populations. Removing the risks associated with the most extreme weather and climate events from the

consequences of global warming diminishes the perceived urgency for reducing fossil fuel emissions. The poorest populations would benefit far more from access to grid electricity and help in reducing vulnerability from extreme weather events, than from reductions to the amount of CO₂ in the atmosphere. Bjorn Lomborg, False Alarm

The uncertainties and complexity of the forces driving the social, biological, and physical dimensions of climate change ensure that we will most likely be surprised by the outcomes. However, there are several features of the climate problem that suggest that climate change related risks will increase in the future. These factors are:⁷⁶

- There is a substantial time lag between the emission of greenhouse gases and the related impacts, and the link to many impacts is not yet fully understood.
- Science is unable to predict long-term impacts accurately enough to provide a strong signpost for action.
- There is large heterogeneity in historical, current and expected future emissions among countries and sectors, and there is no single culprit.
- Variance and heterogeneity of climate related hazards and benefits are large, and winners and losers may change over time.
- There is large heterogeneity in vulnerability among countries, sectors and ecosystems.

The question of intergenerational equity is of special importance for emerging risks, owing to the lag between the emissions of greenhouse gases and the expected occurrence of the damage. There is no simple way to decide what duty of care we owe to future generations, but the IPCC's

socioeconomic pathways for the 21st century all have the world being better off by 2100, even under the most extreme emissions scenarios.

A key to securing meaningful action to reduce climate change risk is to clearly separate the incremental, emerging risks associated with long-term changes in average conditions—which can be addressed to some extent in the long term by reducing greenhouse gas emissions—from the emergency risks associated with extreme weather and climate events, which need to be addressed in both the present and future climate. Any assessment of climate risk needs to approach these two kinds of risk differently, depending on the nature of the decisions it aims to inform.

Once the incremental risks are separated from the emergency risks, the perception of urgency in reducing emissions is diminished. It becomes far more important to develop strategies for managing atmospheric greenhouse gases in a way that supports a transition that does not have adverse impact on security, the economy, industry and agriculture. The challenges for risk assessment are then to identify transition risks associated with proposed solutions to mitigate the rising atmospheric CO₂ content.

At this point, assessing the transition risks of eliminating fossil fuels is arguably more important than attempting to refine our assessments of the deeply uncertain incremental risks associated with fossil fuel emissions. Consequences of the transition are associated with a fairly solid knowledge base, leading many people to be more concerned about transition risks than they are about the more uncertain risks from climate change itself that are associated with a far weaker knowledge base.^{77 78 79}

Assessments of emergency risk associated with extreme weather and climate events generally focus on event type, sectoral impacts or regional assessments. Too many of these assessments are seemingly intended to build political will for eliminating fossil fuel emissions rather than conducting a serious assessment of emergency risk including systemic aspects.

A laudable example of weather emergency risk assessment relates to the ARkStorm scenario described in Section 9.4.2, related to extreme winter flooding in central California.⁸⁰ The state of California's ShakeOut Earthquake Scenario to support preparedness for a major earthquake demonstrated how postulating a hypothetical but plausible catastrophe provides a basis for better examining the interdependencies in social structure and infrastructure and expose choke-points and vulnerabilities.⁸¹ The ARkStorm risk assessment project engaged emergency planners, businesses, universities, government agencies, and others. Following a thorough development of the storm scenario and its direct impacts on inundation and landslides, they assessed secondary impacts on highways, electricity systems, wastewater treatment, water supply, dams, levees, telecommunications, agriculture, buildings, evacuation and sheltering strategies, business interruption, truck transport, and environmental and health issues associated with hazardous materials. The ARkStorm scenario and risk assessment informed community decision-making and is helping communities increase their resilience to severe California winter storms.⁸²

In assessing emergency risk from extreme weather/climate events, there are some key principles to follow:⁸³

1. Emergency risk from extreme weather/climate events is dominated by plausible worst-case events. Looking at extreme event data back to 1950, and calculating return periods, isn't useful here. Global climate models are of no direct use for

extreme event scenarios. Of the three extreme events selected in Section 9.4, the Florida hurricane scenario was based on data from 1935, the ARkStorm scenario was based on data from 1861/62, and the south Asian monsoon failure was based on data from 1756-1768 – the latter two cases were informed not only by historical records but also by paleoclimate reconstructions.

2. Consider all events, even if their probability of occurrence in a particular location is low. The low probability/high impact events, provided that the events are judged to be plausible or have occurred in the past, are associated with the greatest risks. Nevertheless, the cumulative impact of weaker events can also be significant.
3. Be holistic. Account for all relevant factors, as far as possible – including human behavior and the complex interactions between different parts of a system. Evaluate both direct and systemic risks across the relevant time and space windows appropriate to the decision process.
4. Assess the current risk from weather/climate extremes, based on historical extreme events and today's societal vulnerabilities. Additional scenarios can be created with incremental effects from global warming.

The seemingly overwhelming challenge of climate risk assessment and the associated political conflicts becomes more tractable by separating the incremental, emerging risk from the emergency risk associated with weather/climate extremes. By regionalizing risk governance, the management approach does not depend on an impossible global agreement for a dubious “perfect” solution that requires moral and political coercion. The regional approach offers a feasible pathway that respects the existing interests and values of the human beings concerned.

This approach works within our existing political institutions (no need for a global government) and offers transparent arguments for action within our present valuational framework, rather than requiring us all to assume a new and narrow set of values.⁸⁴

10.3.3 Climate change versus COVID-19 risk

“There is no power for change greater than a community discovering what it cares about” – writer Margaret Wheatley⁸⁵

The outbreak of the COVID-19 pandemic in the end of 2019 has generated or contributed to a series of interconnected financial, societal, and political crises on a global scale. This has triggered comparative studies of systemic risks of pandemics and climate change, which share many commonalities despite obvious differences.⁸⁶

Both pandemic and climate risks are systemic, in that their impacts propagate rapidly across an interconnected world. Both COVID-19 and climate change risks are nonstationary, with past probabilities and distributions of occurrences rapidly shifting and proving to be inadequate for future projections. Both risks are nonlinear, in that their socioeconomic impact grows disproportionately and even catastrophically once certain thresholds are breached (such as hospital capacity to treat pandemic patients). Both COVID-19 and climate change are risk multipliers, that highlight and exacerbate hitherto untested vulnerabilities inherent in the financial, energy, food and healthcare systems and the overall economy. Both risks affect disproportionately the world’s most vulnerable populations.⁸⁷

However, the timescales of both the occurrence and the resolution of pandemics and climate hazards are different. Pandemic risk is measured in weeks, months, and years; climate risk is

measured in decades and centuries. A pandemic presents imminent, discrete, and directly discernable dangers. By contrast, the risks from climate change, are gradual, cumulative, and distributed, manifesting themselves over time and in spatially heterogeneous way.⁸⁸ The primary difference between the pandemic and climate hazards is that the salience of the threat and perceived urgency of dealing with it.⁸⁹

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From: Ross McKittrick <ross.mckittrick@gmail.com>
Sent: Thursday, May 29, 2025 10:53 AM
To: Steven Koonin
Cc: John Christy; Roy Spencer; Travis Fisher; Judith Curry; Josh Loucks
Subject: Re: NCA5: Scientific assessment or social engineering?

Without even reading the NASEM report I assume it's useless. The problem is they draw experts from govt agencies and universities. That crowd knows that the NCA serves a partisan purpose so they'll pull their punches to prevent giving fodder to the enemies of the movement.

The data show universities are about 95/5 dems/gop and not only that, but among the dems the party identification is "strong" versus mostly "weak" or "leans" among gop. So draw a random sample from academia (ensuring a "wide range" of views blah blah blah) and you end up with left and further left. Up until recently we had to go along with the illusion that expert panels can be relied upon to provide balanced scientific advice but the obvious bias of the IPCC and NCA, among others (CDC, WHO etc) have killed that expectation. They let themselves be colonized by the left and now they've lost any claim on public trust.

RPJr posted this data from a recent UChicago survey

[Ivy League Universities like Harvard and Yale]
...On a scale of 1 to 5 – where 1 means you think the institution is your enemy and 5 means you think the institution is your friend – where on this scale would you place yourself?

OPORI/NOPIC 5/21 to 5/25/25	Total	Dem	Ind	Rep
1 - Enemy	11.1%	3.4%	12.2%	20.5%
2	17.2%	8.9%	18.1%	28.2%
3	45.1%	48.8%	50.3%	41.1%
4	14.5%	22.2%	10.4%	7.7%
5 - Friend	10.5%	18.6%	6.0%	3.4%
DON'T KNOW	0.3%	0.4%	0.1%	0.3%
SKIPPED ON WEB	1.3%	1.0%	2.8%	0.7%
N=	2131	1012	322	794

Almost 50% of republicans (and 30% of independents) now view ivy league universities not just as useless but as their enemies. The antagonism is fully deserved. The NASEM needs to commission a report explaining why the universities became such one-sided intolerant monocultures and what can be done to fix it, and until they tackle that issue they too deserve the DOGE treatment.

On Thu, May 29, 2025 at 10:09 AM Steven Koonin <steven.koonin@gmail.com> wrote:

I've downloaded the report (<https://nca2023.globalchange.gov/downloads/>) There's very little of the foundational science in its 1834 pages(!) that's amenable to serious scientific critique.

I also attach the NASEM review of the NCA5 draft, as well as the authors' responses to that review.

And here's a link to the "gold standard" EO: <https://www.whitehouse.gov/presidential-actions/2025/05/restoring-gold-standard-science/> . A reminder that its criteria are:

- (i) reproducible;
- (ii) transparent;
- (iii) communicative of error and uncertainty;
- (iv) collaborative and interdisciplinary;
- (v) skeptical of its findings and assumptions;
- (vi) structured for falsifiability of hypotheses;
- (vii) subject to unbiased peer review;
- (viii) accepting of negative results as positive outcomes; and
- (ix) without conflicts of interest.

SEK

From: John Christy <climateman60@gmail.com>

Sent: Thursday, May 29, 2025 9:58 AM

To: Ross McKittrick <ross.mckittrick@gmail.com>

Cc: Roy Spencer <roywspencer@hotmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>; Steven Koonin <steven.koonin@gmail.com>; Judith Curry <curry.judith@gmail.com>; Josh Loucks <loucksj14@gmail.com>

Subject: Re: NCA5: Scientific assessment or social engineering?

This mirrors the word usage from the briefing we received from the head of NCA5.

John C.

On Thu, May 29, 2025 at 8:56 AM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

I guess people used to the NCA genre are going to find our report totally off-topic.

On Thu, May 29, 2025 at 7:01 AM Roy Spencer <roywspencer@hotmail.com> wrote:

I did keyword counts in NCA5, and got the following results:

Mentions of RCP/SSP Scenarios (other than definitions):

RCP8.5/SSP5-8.5: 105 (53%)

RCP6.0/SSP3-7.0: 8 (4%)

RCP4.5/SSP2-4.5: 66 (33%)

RCP2.6/SSP1-2.6: 19 (10%)

Social/Societal keywords

Indigenous/Tribes/Tribal: 1,679

Culture/Culturally: 854

Equity/Equitable: 572

Sustainable: 295

Inequality/Unequal: 201

Racism/Racial: 153

Low-Income: 105

Injustice: 94

Communities of Color: 67

Minorities: 37

From: Travis Fisher [travis.scott.fisher@gmail.com]
Sent: 5/15/2025 3:24:30 AM
To: Steven Koonin [steven.koonin@gmail.com]
CC: Ross McKittrick [ross.mckittrick@gmail.com]; Judith Curry [curry.judith@cfandclimate.com]; John Christy [climateman60@gmail.com]; Roy W. Spencer [roywspencer@hotmail.com]
Subject: Re: New folder: 01.Report Draft
Attachments: 1 CO2.v.CACs.May11[SEK] - TF comment.docx

I'm just now seeing this thread after opening Chapter 1 for review. From now on, I'll work from the clean versions.

My one comment on Ch1 is attached.

On Wed, May 14, 2025 at 7:18 PM Steven Koonin <steven.koonin@gmail.com> wrote:

That works. Thanks.

SEK

From: Ross McKittrick <ross.mckittrick@gmail.com>
Sent: Wednesday, May 14, 2025 7:17 PM
To: Steven Koonin <steven.koonin@gmail.com>
Cc: Judith Curry <curry.judith@cfandclimate.com>; John Christy <climateman60@gmail.com>; Roy W. Spencer <roywspencer@hotmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>
Subject: Re: New folder: 01.Report Draft

This should get you in

https://www.dropbox.com/sc/fo/wahx6lpwzu33m5vyrrix/ANTU1qAQJ-zXCFzP_gsJcOs?rlkey=llz3qj9v46elt5f4ywwxq7p8c&dl=0

This is for the parent folder. Let me know if it doesn't work.

On Wed, May 14, 2025 at 6:41 PM Steven Koonin <steven.koonin@gmail.com> wrote:

Can you please send a link to the new folder?

Thanks.

Steven E. Koonin

> On May 14, 2025, at 15:27, Ross McKittrick <ross.mckittrick@gmail.com> wrote:

>

>

> Following our meeting today I created a new folder containing clean copies (all past tracked changes accepted) of all chapters.

> There are some marginal queries and in-line comments remaining to be resolved, missing Figure captions in a couple of places etc. If you are able to supply the missing info go ahead and do so. We will soon need to

sign off on final text versions so please read through them.

> I propose that these should be the versions we talk through next week.

>

> Question: should there be a single list of references at the very end or should each chapter have its own reference list? Initially I thought the former but now I lean towards the latter.

>

1 Carbon dioxide as pollutant

In 2007, the Supreme Court ruled that GHGs (CO₂ among them) were “pollutants” subject to regulation under that Clean Air Act. That framework defines six types of so-called Criteria Air Contaminants (EPA, undated): .

While the definition of “pollutant” is ultimately a legal one, there are important scientific distinctions between CO₂ and the Criteria Air Contaminants—particulate matter, ground-level ozone, Sulfur Dioxide, Nitrogen Dioxide, Lead and carbon monoxide (CO). The latter are subject to regulatory control because they cause local problems depending on concentrations that include nuisances (odor, visibility), damage to plants, and, at high enough exposure levels, toxicological effects in humans. In contrast, CO₂ is odorless, does not affect visibility and has no toxicological effects at ambient levels. It is a naturally-occurring part of the atmosphere and a key component of human and plant respiration. CO₂ is essential for plant photosynthesis and higher levels are generally considered beneficial for vegetation. In these aspects, it is similar to water.

Ambient outdoor air today contains about 420 parts per million (ppm) CO₂, increasing at about 2 ppm per year. The US Occupational Safety and Health Administration issues guidelines for indoor workplaces in which elevated CO₂ might be encountered, such as where dry ice is used. The Permissible Exposure Limit is 5,000 ppm over 8 hours (OSHA 2024). Allen *et al.* (2015) reported evidence of diminished performance on some cognitive tasks among workers in office cubicles when exposed to CO₂ levels above 1,000-1,500 ppm. These levels are far larger than any plausible ambient outdoor value through the end of the 22nd century.

The growing amount of CO₂ in the atmosphere directly influences the earth system by promoting plant growth (global greening), thereby enhancing agricultural yields, and also by neutralizing ocean alkalinity. But the primary concern about CO₂ is its role as a greenhouse gas (GHG), that alters the earth’s energy balance. How the climate will respond to that influence is a complex question that will occupy much of this report.

Massachusetts v. EPA (2006) <https://www.oyez.org/cases/2006/05-1120>

US Environmental Protection Agency (Undated) Criteria Air Pollutants. <https://www.epa.gov/criteria-air-pollutants> accessed April 29 2025.

US Occupational Health and Safety Administration (2024) “OSHA Occupational Chemical Database: Carbon Dioxide” <https://www.osha.gov/chemicaldata/183>

Allen, Joseph G, Piers MacNaughton, Usha Satish, Suresh Santanam, Jose Vallarino and John D.S. Spengler (2015) Associations of Cognitive Function Scores with Carbon Dioxide, Ventilation, and Volatile Organic Compound Exposures in Office Workers: A Controlled Exposure Study of Green and Conventional Office Environments. *Environmental Health Perspectives* 124(6) pp. 805-812 <https://doi.org/10.1289/ehp.1510037>

From: Ross McKittrick [ross.mckittrick@gmail.com]
Sent: 5/18/2025 4:53:15 PM
To: Roy Spencer [roywspencer@hotmail.com]
CC: Judith Curry [curry.judith@cfanclimate.com]; John Christy [climateman60@gmail.com]; Steven Koonin [steven.koonin@gmail.com]; Travis Fisher [travis.scott.fisher@gmail.com]
Subject: Re: new text: declining planetary albedo
Attachments: Declining planetary albedo.May18.[JC][RS]RM).docx

This looks excellent Judy.

I added a couple of sentences to the first paragraph for the benefit of non-experts. Agree with Roy that the connection to recent warmth is important.

On Sun, May 18, 2025 at 12:30 PM Roy Spencer <roywspencer@hotmail.com> wrote:

I made several edits... One being the reason why decreasing albedo is even being mentioned: record global -average warmth.

From: Judith Curry <curry.judith@cfanclimate.com>
Sent: Sunday, May 18, 2025 10:42 AM
To: John Christy <climateman60@gmail.com>; Roy W. Spencer <roywspencer@hotmail.com>; Ross McKittrick <ross.mckittrick@gmail.com>; Steven Koonin <steven.koonin@gmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>
Subject: new text: declining planetary albedo

Ross suggested I write a section on the declining planetary albedo, for the attribution chapter. I'm sending the text for your comments before inserting into the chapter, since it is new material and I'm not sure how much of this we should actually include. In particular, I think Roy could be helpful here. Look forward to your comments.

Declining planetary albedo and recent record warmth

Planetary albedo is the fraction of incoming solar radiation that is reflected back into space by reflective surfaces like cloud tops and snow, rather than being absorbed at the surface. Earth's planetary albedo is approximately 30%, meaning almost a third of the sunlight that reaches Earth is directly reflected back to space. A lower albedo implies more solar energy is absorbed at the surface to be then re-radiated as heat into the atmosphere. Hence, other things being equal, a decline in Earth's albedo is associated with a warming of the atmosphere.

Arguably the most striking change to the Earth's climate system in the 21st century is a significant reduction in planetary albedo since 2015, which has coincided with at least two years of record global warmth. Figure xxx shows the planetary albedo variations since 2000, when we have good satellite observations. The 0.5% reduction in planetary albedo since 2015 corresponds to an increase of 1.7 W/m² in solar energy averaged over the planet (Hansen and Karecha, 2025). For reference, doubling of CO₂ has a direct radiative impact of about 1.2 W/m².

Looking back prior to 2000 with less adequate data, Gossling et al. (2025) assessed that planetary albedo was relatively low around the 1940's and 50's, before industrial aerosol precursor emissions led to global dimming until the 1980's. The strongest planetary albedo excursions were high-albedo episodes caused by volcanic eruptions, such as after the Mount Pinatubo eruption in 1991. Although uncertain, the 2023 planetary albedo minimum may have been the lowest since at least 1940.

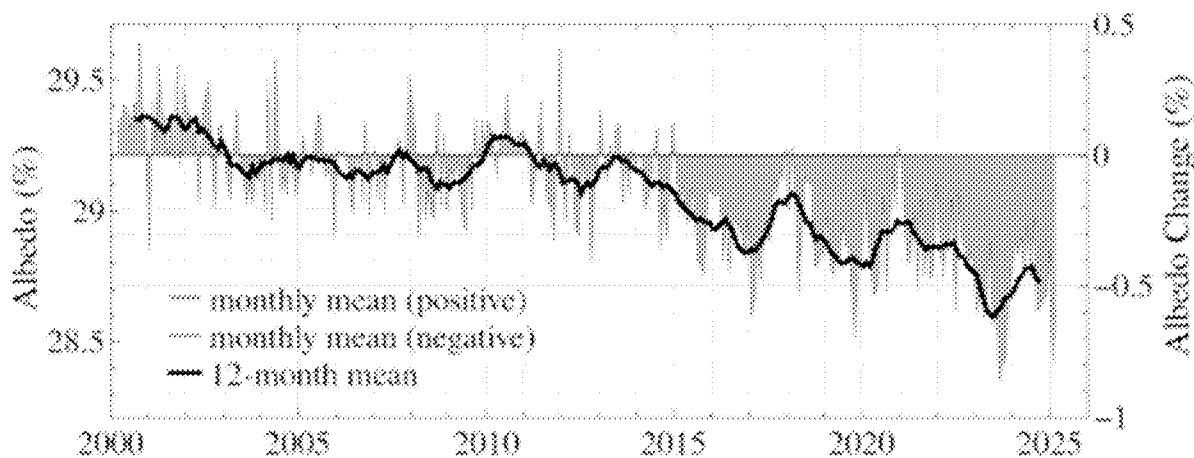


Figure xxx. Earth's albedo (reflectivity, in percent), with seasonality removed. From Hansen and Karecha (2025)

Changes in surface characteristics can't explain this decrease in planetary albedo since 2015:

- Arctic sea ice extent has declined by about 5% since 1980 (https://nsidc.org/data/seaice_index/images/s_plot_hires.png), although following 2007 there has been a pause in the Arctic sea ice decline (England et al., 2025)
- Regarding Antarctic sea ice, the IPCC AR6 concludes that "There has been no significant trend in Antarctic sea ice area from 1979 to 2020 due to regionally opposing trends and large internal variability." (SPM, A.1.5)
- Northern hemispheric snow cover has been slowly declining since 1967, with barely significant trends. The data show the Northern Hemisphere has snowier winters, accompanied by more rapid melt in spring and summer.
<http://climate.rutgers.edu/snowcover/>

- Global greening (Chapter 2) is contributing the decrease in planetary albedo, as forests have a lower albedo than open lands or snow. However, there is some evidence that forests increase cloud cover (high reflectivity), which counteracts the direct albedo increase associated with increasing forested area.

Changes in surface reflectivity are contributing to a small, slow decline in planetary albedo. However, these changes cannot explain the sharp decline in planetary albedo beginning in 2015. Further, any changes in surface albedo are effectively damped by about a factor 3 on average, primarily due to cloud masking (Loeb et al. 2019). Surface albedo changes have thus contributed only weakly to the recent planetary albedo decline, particularly when averaged annually and globally.

This leaves the most likely explanation for the sharp albedo decline as being caused by changes in atmospheric aerosols and/or clouds.

Aerosols are small particles in the atmosphere that reflect sunlight and can interact with cloud processes to make the clouds more reflective. Aerosols have both natural origins (e.g dust from soils, wildfires) as well as human origins from combustion (including fossil fuels). Regions that are greening and/or have an increase in rainfall may be producing less dust. In terms of pollution aerosol, new ship fuel regulations aimed at reducing sulfur emissions were implemented in three phases, in 2010, 2015 and 2020. Sulfate particles reflect solar radiation. Cleaner air means less solar radiation is reflected, which contributes to surface warming. Indirect effects of sulfate aerosols include increasing the reflectivity of low-level clouds in the subtropics. There is controversy surrounding the importance of this change in sulfate emissions to the Earth's radiation balance (Hodnebrog et al., 2024; Yuan et al., 2024), but the restriction of this effect to major shipping routes suggests a small global impact (Schmidt, 2024).

This leaves changes in clouds as the primary candidate to explain the decline in global albedo since 2015. Two recent papers (Loeb et al., 2024; Gosling et al 2024) have addressed recent variations in cloud properties. By considering satellite and reanalysis data, Loeb et al. found that decreases in low and mid-level clouds since 2015 are the primary reason for decreasing planetary albedo in the northern hemisphere, whereas in the southern hemisphere the decrease in planetary albedo is primarily from decreases in mid-level clouds across all latitude zones. Gossling et al. (2025) found that cloud anomalies were mainly due to reduced low-level clouds. Regions with coherent low-level cloud reductions over the past decade include the warm pool region around the Maritime Continent and the northern extratropical western Pacific, as well as large parts of the Atlantic and adjacent land regions. The reduction of global cloud cover identified in these analyses since 2015 is 1-2 percent.

Two causes have been posited for the declining cloud cover over the past decade:

- Natural climate variability
- Changes in low cloud cover associated with warming sea surface temperatures, implying an emerging positive feedback to climate change (Hansen and Karecha, 2025)

The existence of a new positive low cloud feedback that began emerging in 2015 is not easy to justify. However, there are numerous natural climate signals during this period that are associated with atmospheric circulation changes that can influence the distribution of clouds:

- The 2014-2016 was the strongest El Nino event on record
- A cold anomaly beginning in 2015 in the subpolar gyre of the North Atlantic reflects a shift in the ocean circulation pattern associated with decadal variability in the Atlantic (Frajka-Williams et al., 2017; Arthun et al. 2021).
- The Pacific Decadal Oscillation (PDO) positive index peaked in 2016, then declined and has been in negative territory since late 2019

- Eruption of the submarine Hunga-Tonga volcano in 2022

Interannual cloud anomalies associated with the El Nino Southern Oscillation (ENSO), which have a significant global signal and strong regional signals especially over the tropical Indian and Pacific Oceans.

The Hunga Tonga eruption is remarkable in its coincidence with the exceptionally low value of planetary albedo in 2023. Gossling et al. (2025) found that the cloud perturbations in 2023 showed a different pattern from the overall pattern since 2015, with reduced cloud cover being most pronounced in the northern hemisphere and tropics. Regional reductions in cloud cover were most pronounced over the eastern Indian Ocean, over South America and extending over the eastern Pacific, as well as over northern North America, in the Southern Ocean around 60S, in the subtropical and eastern North Atlantic, and in parts of the North Pacific.

The Hunga Tonga eruption was unusual in that it injected large amounts of water vapor into the stratosphere, in addition to sulfate particles. Early publications focused on the impacts to stratospheric circulations and the direct radiative impact. In 2025, papers are emerging that examine the indirect effects of Hunga Tonga on surface climate using ensemble simulations from earth system models (Bednarz et al, 2025; Kuchar et al., 2025). These papers found statistically significant impacts on regional climates that were driven by circulation changes from couplings between the stratosphere and troposphere. These papers indicate the complex interactions between volcanic activity and climate dynamics. More research is needed to untangle any impacts of Hunga Tonga eruption on planetary albedo.

In summary, the decline in planetary albedo and the concurrent decline in cloudiness have emphasized the importance of clouds and their variations to global climate variability and change. A change of 1 to 2 percent in global cloud cover has a greater radiative impact on the climate than the direct radiative effect of doubling CO₂. While it is difficult to untangle causes of the trend, the competing explanations for the cause of the declining cloud cover have substantial implications for assessing the Equilibrium Climate Sensitivity and also the attribution of the recent warming. An additional 10 years of data should help clarify whether this is a strong positive cloud feedback associated with warming, or a temporary fluctuation driven by natural variability

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identify a decadal mode of atmosphere–ocean variability in the North Atlantic with a dominant time scale of 13–18 years. Large-scale atmospheric circulation anomalies drive SST anomalies both through contemporaneous air–sea heat fluxes and through delayed ocean circulation changes, the latter involving both the meridional overturning circulation and the horizontal gyre circulation.

From: Roy Spencer <roywspencer@hotmail.com>
Sent: Sunday, May 18, 2025 12:31 PM
To: Judith Curry; John Christy; Ross McKittrick; Steven Koonin; Travis Fisher
Subject: Re: new text: declining planetary albedo
Attachments: Declining planetary albedo-RS-edits.docx

I made several edits... One being the reason why decreasing albedo is even being mentioned: record global-average warmth.

From: Judith Curry <curry.judith@cfanclimate.com>
Sent: Sunday, May 18, 2025 10:42 AM
To: John Christy <climateman60@gmail.com>; Roy W. Spencer <roywspencer@hotmail.com>; Ross McKittrick <ross.mckittrick@gmail.com>; Steven Koonin <steven.koonin@gmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>
Subject: new text: declining planetary albedo

Ross suggested I write a section on the declining planetary albedo, for the attribution chapter. I'm sending the text for your comments before inserting into the chapter, since it is new material and I'm not sure how much of this we should actually include. In particular, I think Roy could be helpful here. Look forward to your comments.

Declining planetary albedo and recent record warmth

Planetary albedo is the fraction of incoming solar radiation that is reflected back into space by the Earth's surface and atmosphere. Earth's planetary albedo is approximately 30%, meaning almost a third of the sunlight that reaches Earth is reflected back to space.

Arguably the most striking change to the Earth's climate system in the 21st century is a significant reduction in planetary albedo since 2015, which has coincided with at least two years of record global warmth. Figure xxx shows the planetary albedo variations since 2000, when we have good satellite observations. The 0.5% reduction in planetary albedo since 2015 corresponds to an increase of 1.7 W/m^2 in solar energy averaged over the planet (Hansen and Karecha, 2025). For reference, doubling of CO_2 has a direct radiative impact of about 1.2 W/m^2 .

Looking back prior to 2000 with less adequate data, Gossling et al. (2025) assessed that planetary albedo was relatively low around the 1940's and 50's, before industrial aerosol precursor emissions led to global dimming until the 1980's. The strongest planetary albedo excursions were high-albedo episodes caused by volcanic eruptions, such as after the Mount Pinatubo eruption in 1991. Although uncertain, the 2023 planetary albedo minimum may have been the lowest since at least 1940.

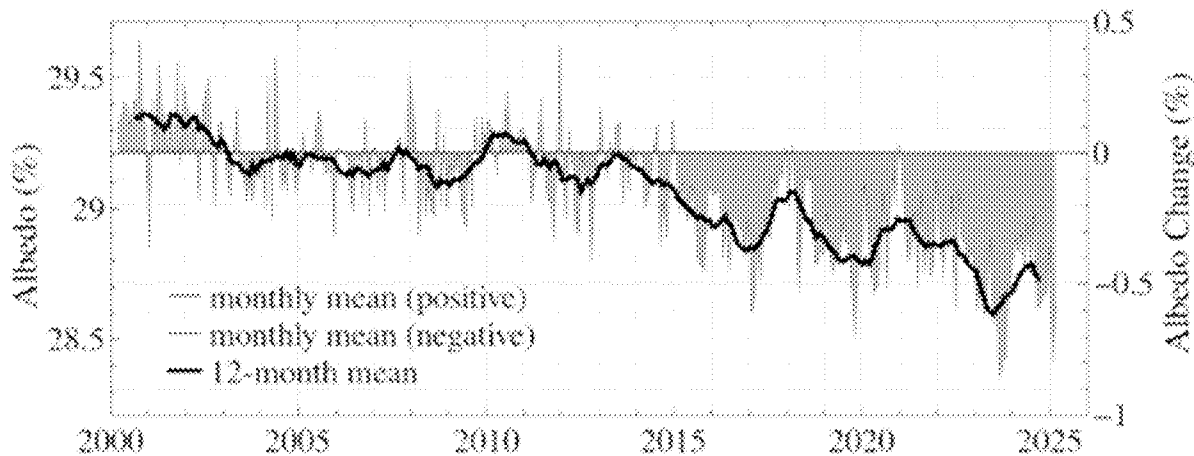


Figure xxx. Earth's albedo (reflectivity, in percent), with seasonality removed. From Hansen and Karecha (2025)

Changes in surface characteristics can't explain this decrease in planetary albedo since 2015:

- Arctic sea ice extent has declined by about 5% since 1980 (https://nsidc.org/data/seaice_index/images/s_plot_hires.png), although following 2007 there has been a pause in the Arctic sea ice decline (England et al., 2025)
- Regarding Antarctic sea ice, the IPCC AR6 concludes that "There has been no significant trend in Antarctic sea ice area from 1979 to 2020 due to regionally opposing trends and large internal variability." (SPM, A.1.5)
- Northern hemispheric snow cover has been slowly declining since 1967, with barely significant trends. The data show the Northern Hemisphere has snowier winters, accompanied by more rapid melt in spring and summer. <http://climate.rutgers.edu/snowcover/>
- Global greening (Chapter 2) is contributing the decrease in planetary albedo, as forests have a lower albedo than open lands or snow. However, there is some evidence that forests increase

cloud cover (high reflectivity), which counteracts the direct albedo increase associated with increasing forested area.

Changes in surface reflectivity are contributing to a small, slow decline in planetary albedo. However, these changes cannot explain the sharp decline in planetary albedo beginning in 2015. Further, any changes in surface albedo are effectively damped by about a factor 3 on average, primarily due to cloud masking (Loeb et al. 2019). Surface albedo changes have thus contributed only weakly to the recent planetary albedo decline, particularly when averaged annually and globally.

This leaves the most likely explanation for the sharp albedo decline as being caused by changes in atmospheric aerosols and/or clouds.

Aerosols are small particles in the atmosphere that reflect sunlight and can interact with cloud processes to make the clouds more reflective. Aerosols have both natural origins (e.g dust from soils, wildfires) as well as human origins from combustion (including fossil fuels). Regions that are greening and/or have an increase in rainfall may be producing less dust. In terms of pollution aerosol, new ship fuel regulations aimed at reducing sulfur emissions were implemented in three phases, in 2010, 2015 and 2020. Sulfate particles reflect solar radiation. Cleaner air means less solar radiation is reflected, which contributes to surface warming. Indirect effects of sulfate aerosols include increasing the reflectivity of low-level clouds in the subtropics. There is controversy surrounding the importance of this change in sulfate emissions to the Earth's radiation balance (Hodnebrog et al., 2024; Yuan et al., 2024), but the restriction of this effect to major shipping routes suggests a small global impact (Schmidt, 2024).

This leaves changes in clouds as the primary candidate to explain the decline in global albedo since 2015. Two recent papers (Loeb et al., 2024; Gosling et al 2024) have addressed recent variations in cloud properties. By considering satellite and reanalysis data, Loeb et al. found that decreases in low and mid-level clouds since 2015 are the primary reason for decreasing planetary albedo in the northern hemisphere, whereas in the southern hemisphere the decrease in planetary albedo is primarily from decreases in mid-level clouds across all latitude zones. Gossling et al. (2025) found that cloud anomalies were mainly due to reduced low-level clouds. Regions with coherent low-level cloud reductions over the past decade include the warm pool region around the Maritime Continent and the northern extratropical western Pacific, as well as large parts of the Atlantic and adjacent land regions. The reduction of global cloud cover identified in these analyses since 2015 is 1-2 percent.

Two causes have been posited for the declining cloud cover over the past decade:

- Natural climate variability
- Changes in low cloud cover associated with warming sea surface temperatures, implying an emerging positive feedback to climate change (Hansen and Karecha, 2025)

The existence of a new positive low cloud feedback that began emerging in 2015 is not easy to justify. However, there are numerous natural climate signals during this period that are associated with atmospheric circulation changes that can influence the distribution of clouds:

- The 2014-2016 was the strongest El Nino event on record
- A cold anomaly beginning in 2015 in the subpolar gyre of the North Atlantic reflects a shift in the ocean circulation pattern associated with decadal variability in the Atlantic (Frajka-Williams et al., 2017; Arthun et al. 2021).
- The Pacific Decadal Oscillation (PDO) positive index peaked in 2016, then declined and has been in negative territory since late 2019
- Eruption of the submarine Hunga-Tonga volcano in 2022

Interannual cloud anomalies associated with the El Niño Southern Oscillation (ENSO), which have a significant global signal and strong regional signals especially over the tropical Indian and Pacific Oceans.

The Hunga Tonga eruption is remarkable in its coincidence with the exceptionally low value of planetary albedo in 2023. Gossling et al. (2025) found that the cloud perturbations in 2023 showed a different pattern from the overall pattern since 2015, with reduced cloud cover being most pronounced in the northern hemisphere and tropics. Regional reductions in cloud cover were most pronounced over the eastern Indian Ocean, over South America and extending over the eastern Pacific, as well as over northern North America, in the Southern Ocean around 60S, in the subtropical and eastern North Atlantic, and in parts of the North Pacific.

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In summary, the decline in planetary albedo and the concurrent decline in cloudiness have emphasized the importance of clouds and their variations to global climate variability and change. A change of 1 to 2 percent in global cloud cover has a greater radiative impact on the climate than the direct radiative effect of doubling CO₂. While it is difficult to untangle causes of the trend, the competing explanations for the cause of the declining cloud cover have substantial implications for assessing the Equilibrium Climate Sensitivity and also the attribution of the recent warming. An additional 10 years of data should help clarify whether this is a strong positive cloud feedback associated with warming, or a temporary fluctuation driven by natural variability

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From: Ross McKittrick <ross.mckittrick@gmail.com>
Sent: Wednesday, July 30, 2025 6:39 PM
To: John Christy
Cc: Steven Koonin; Judith Curry; Roy W. Spencer; Travis Fisher; Josh Loucks
Subject: Re: New York Times follow-up inquiry

I wrote:

Dear Maxine

As I believe my coauthors have stated, the report will soon be open for public comment and we will carefully review the expert feedback and make revisions where warranted.

Sincerely,

On Wed, Jul 30, 2025 at 6:25 PM John Christy <climateman60@gmail.com> wrote:

I got that message too and replied with a sermon asking her to give us time to answer these through an organized process because science is often slow and messy.

John C.

On Wed, Jul 30, 2025 at 4:27 PM Steven Koonin <steven.koonin@gmail.com> wrote:

Steven E. Koonin

Begin forwarded message:

From: Maxine Joselow <maxine.joselow@nytimes.com>
Date: July 30, 2025 at 15:18:36 MDT
To: Steven Koonin <steven.koonin@gmail.com>
Subject: **Re: New York Times follow-up inquiry**

Steve, my deadline has been extended to 10am ET tomorrow, and I'm just following up with some other criticisms of the report, in case you would like to address any of them:

- The report suggests that solar activity may be an “underestimated” contributor to warming this century, citing a recent paper that has been sharply criticized. But a 2021 report by the Intergovernmental Panel on Climate Change, which was compiled by hundreds of scientists, determined that human activity is responsible for essentially all of the observed global warming seen to date, while natural factors like sunspots have had little effect.
- The report states that U.S. tide gauges “show no obvious acceleration in sea-level rise beyond the historical average rate.” But satellite measurements for the past 30 years have found that sea level rise is accelerating globally. The authors seem to have selectively chosen data from certain tide gauges that supported their point, said Bob Kopp, a climate scientist at Rutgers University.

On Wed, Jul 30, 2025 at 12:51 PM Maxine Joselow <maxine.joselow@nytimes.com> wrote:
Thank you for getting back to me, Steve. There is a strict firewall between the New York Times's objective news section and its opinions section, so unfortunately I cannot assist with an op-ed. Please let me know if you have any additional comment.

Best,
Maxine

On Wed, Jul 30, 2025 at 12:13 PM Steven Koonin <steven.koonin@gmail.com> wrote:
Maxine- sound bites produced on short notice filtered through a non-expert reporter are not conducive for serious scientific communication.

If your paper will allow me an OpEd, I can respond to the questions you pose. (BTW, I note the WSJ sometimes publishes OpEds that differ dramatically from its editorial positions.)

In addition, DOE has, or soon will have, a comment portal. I and my coauthors are committed to giving serious responses to all serious criticisms.

Steven E. Koonin

On Jul 30, 2025, at 09:47, Maxine Joselow <maxine.joselow@nytimes.com> wrote:

Hi again, Steve,

I hope you are well. This is Maxine Joselow at the New York Times. I'm circling back now that you're listed as one of the authors of this DOE report. I wanted to reach out again for fairness' sake to offer you the chance to respond to critical comments.

How would you respond to criticism from other climate scientists who say the report cherry-picks data and presents a misleading overview of the scientific consensus? In particular, how would you respond to criticism that the report highlights the positive effects of carbon dioxide for plants and global "greening" while downplaying the negative effects of CO2 on global temperature rise and on declining crop yields?

Please let me know either way when you get the chance. My deadline is 4pm ET, and I can be reached via email or via cell at 202-948-1924.

Thanks,
Maxine

--

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Signal: MaxineJ.55

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From: Ross McKittrick <ross.mckitrick@gmail.com>
Sent: Wednesday, July 30, 2025 6:41 PM
To: John Christy
Cc: Steven Koonin; Judith Curry; Roy W. Spencer; Travis Fisher; Josh Loucks
Subject: Re: New York Times follow-up inquiry

I got an email from Jake Spring of the WaPo wanting to do a phone interview. I will decline the request, but did any of you get that request and do you plan to accept?

I'd prefer if we had just one person doing the media interviews, and if Steve is willing he has my vote.

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To: John Christy
Cc: Steven Koonin; Ross McKittrick; Judith Curry; Roy W. Spencer; Josh Loucks
Subject: Re: New York Times follow-up inquiry

Andrea Woods in DOE's office of public affairs is working on a statement now that you all can use to respond to sticky questions if you like.

It will say something like: this is an important substantive issue that deserves the detailed review provided by DOE's public comment process. We encourage everyone to submit their comments in the docket and we appreciate your interest, etc.

The point is to drive comments into the docket, both to make sure the docket is robust (although I'm sure it will be!) and to save you all the time and effort of playing whack-a-mole (protecting you all from the political theater is also an important part it).

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Maxine- sound bites produced on short notice filtered through a non-expert reporter are not conducive for serious scientific communication.

If your paper will allow me an OpEd, I can respond to the questions you pose. (BTW, I note the WSJ sometimes publishes OpEds that differ dramatically from its editorial positions.)

In addition, DOE has, or soon will have, a comment portal. I and my coauthors are committed to giving serious responses to all serious criticisms.

Steven E. Koonin

On Jul 30, 2025, at 09:47, Maxine Joselow <maxine.joselow@nytimes.com> wrote:

Hi again, Steve,

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How would you respond to criticism from other climate scientists who say the report cherry-picks data and presents a misleading overview of the scientific consensus? In particular, how would you respond to criticism that the report highlights the positive effects of carbon dioxide for plants and global "greening" while downplaying the negative effects of CO2 on global temperature rise and on declining crop yields?

Please let me know either way when you get the chance. My deadline is 4pm ET, and I can be reached via email or via cell at 202-948-1924.

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The New York Times
Cell: 202-948-1924
Signal: MaxineJ.55

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From: Steven Koonin <steven.koonin@gmail.com>
Sent: Wednesday, July 30, 2025 6:51 PM
To: Ross McKittrick
Cc: John Christy; Steven Koonin; Judith Curry; Roy W. Spencer; Travis Fisher; Josh Loucks; andrea.woods@hq.doe.gov
Subject: Re: New York Times follow-up inquiry

I got a similar request. Consulted with Andrea and learned DOE had already given him a statement. So I'm not going to reply.

However, I'm thinking about saying something like the following to such requests:

The Secretary and we authors are committed to "getting it right" and understand that scientific criticism and rebuttal is key to that process. However, impromptu sound bites filtered through non-expert reporters not productive toward that end. Rather, the DOE has established a comment portal and all serious criticisms submitted will be responded to seriously.

Thoughts?
Steven Koonin

On Jul 30, 2025, at 16:41, Ross McKittrick <ross.mckittrick@gmail.com> wrote:

I got an email from Jake Spring of the WaPo wanting to do a phone interview. I will decline the request, but did any of you get that request and do you plan to accept?
I'd prefer if we had just one person doing the media interviews, and if Steve is willing he has my vote.

On Wed, Jul 30, 2025 at 6:39 PM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

I wrote:

Dear Maxine

As I believe my coauthors have stated, the report will soon be open for public comment and we will carefully review the expert feedback and make revisions where warranted.

Sincerely,

On Wed, Jul 30, 2025 at 6:25 PM John Christy <climateman60@gmail.com> wrote:

I got that message too and replied with a sermon asking her to give us time to answer these through an organized process because science is often slow and messy.

John C.

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From: Maxine Joselow <maxine.joselow@nytimes.com>

Date: July 30, 2025 at 15:18:36 MDT

To: Steven Koonin <steven.koonin@gmail.com>

Subject: Re: New York Times follow-up inquiry

Steve, my deadline has been extended to 10am ET tomorrow, and I'm just following up with some other criticisms of the report, in case you would like to address any of them:

- The report suggests that solar activity may be an “underestimated” contributor to warming this century, citing a recent paper that has been sharply criticized. But a 2021 report by the Intergovernmental Panel on Climate Change, which was compiled by hundreds of scientists, determined that human activity is responsible for essentially all of the observed global warming seen to date, while natural factors like sunspots have had little effect.
- The report states that U.S. tide gauges “show no obvious acceleration in sea-level rise beyond the historical average rate.” But satellite measurements for the past 30 years have found that sea level rise is accelerating globally. The authors seem to have selectively chosen data from certain tide gauges that supported their point, said Bob Kopp, a climate scientist at Rutgers University.

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John C.

Sent from my iPhone

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Subject: Re: New York Times inquiry

I received the CNN inquiry too - played Sgt Schultz from Hogan's Heros ... I know nothing!

Interesting Judy and Ross are under the radar for the moment - must be the lack of creation of a DoE ID badge. I wonder who the two DoE sources speaking without authority are?

John C.

On Tue, Jul 8, 2025 at 12:04 PM Steven Koonin <steven.koonin@gmail.com> wrote:
It sure would be nice to get a message out through more favorable media- WSJ for example.

Something like we're working on a more complete and transparent picture of climate science.

Steven E. Koonin

On Jul 8, 2025, at 12:59, Travis Fisher <travis.scott.fisher@gmail.com> wrote:

My recommendation is to not respond.

Please let me know if there's a message you want me to relay to the DOE's press office though.

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Subject: RE: New York Times inquiry

Yes, it is pretty thin.

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From: Maxine Joselow <maxine.joselow@nytimes.com>
Date: July 7, 2025 at 22:19:55 EDT
To: steven.koonin@gmail.com
Subject: Re: New York Times inquiry

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Just trying you one last time before the story runs. I'm planning to report that you are listed as a special government employee in the DOE internal email system, along with John Christy and Roy Spencer. If there's any comment you'd like to provide, please let me know. Thank you.

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On Wed, Jul 2, 2025 at 10:09 AM Maxine Joselow
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Do you have any comment on this information? Please let me know at your earliest convenience -- I can be reached via email or via cell at 202-948-1924 -- and thanks again for considering this request.

Thanks,

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On Tue, Jul 1, 2025 at 5:11 PM Maxine Joselow
<maxine.joselow@nytimes.com> wrote:

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<~WRD0003.jpg>
Judith Curry, President
CFAN - Climate Forecast Applications Network
Reno, NV USA
curry.judith@cfanclimate.com | +1.404.803.2012
<http://www.cfanclimate.net>

From: Judith Curry <curry.judith@gmail.com>
Sent: Tuesday, July 8, 2025 2:45 PM
To: Ross McKittrick
Cc: Travis Fisher; Steven Koonin; Roy Spencer; John Christy; Josh Loucks
Subject: Re: New York Times inquiry

don't underestimate the paranoia of climate alarmists :)

On Tue, Jul 8, 2025 at 11:41 AM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

I don't think anything is breaking, CNNis just regurgitating the NYT. MSNBC will be next but without any new details the story will fizzle. So I suggest not giving any info.

They clearly don't know what's happening although the guesses are reasonable. I prefer to let them speculate and collect crazy quotes from the usual corners and then release our work on our own timetable.

On Tue, Jul 8, 2025 at 2:31 PM Travis Fisher <travis.scott.fisher@gmail.com> wrote:

Fully agree!

I need to set up a notice and comment structure for the CWG report. We may also have to wait until the EPA releases its rule (as early as July 21), although I'd rather move first. That type of decision is well above my pay grade.

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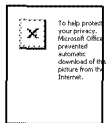
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On Mon, Jul 7, 2025 at 7:32 PM Steven Koonin <steven.koonin@gmail.com> wrote:

Maxine making one last try. I will not respond.

Steven Koonin

Begin forwarded message:

From: Maxine Joselow <maxine.joselow@nytimes.com>
Date: July 7, 2025 at 22:19:55 EDT
To: steven.koonin@gmail.com
Subject: Re: New York Times inquiry

Hi Steve,

Just trying you one last time before the story runs. I'm planning to report that you are listed as a special government employee in the DOE internal

email system, along with John Christy and Roy Spencer. If there's any comment you'd like to provide, please let me know. Thank you.

Best,

Maxine

On Wed, Jul 2, 2025 at 10:09 AM Maxine Joselow
<maxine.joselow@nytimes.com> wrote:

Hi again, Steve,

I'm just following up on this inquiry. I'm planning to report that you're helping to lead a team of Energy Department employees who have been tasked with crafting a technical support document that justifies the repeal of the endangerment finding. Further, you are listed as a "special government employee" in the DOE internal email system.

Do you have any comment on this information? Please let me know at your earliest convenience -- I can be reached via email or via cell at 202-948-1924 -- and thanks again for considering this request.

Thanks,

Maxine

On Tue, Jul 1, 2025 at 5:11 PM Maxine Joselow
<maxine.joselow@nytimes.com> wrote:

Hi Steve,

I hope this email finds you well. This is Maxine Joselow, a climate reporter for the New York Times. We previously spoke when I was at the Washington Post. I'm working on a story about the Environmental Protection Agency's forthcoming proposal to repeal the endangerment finding for greenhouse gases. Would you have time to speak with me about this sometime on Wednesday (tomorrow)? And if so, could you

remind me of your phone number? Please let me know when you get the chance, and thank you for considering this request.

Best,

Maxine

--

Maxine Joselow
Climate Reporter
The New York Times
Cell: 202-948-1924
Signal: MaxineJ.55

--

Maxine Joselow
Climate Reporter
The New York Times
Cell: 202-948-1924
Signal: MaxineJ.55

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<~WRD0003.jpg>

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From: John Christy <climateman60@gmail.com>
Sent: Thursday, July 31, 2025 12:00 PM
To: Ross McKittrick
Cc: Steven Koonin; Judith Curry; Roy W. Spencer; Travis Fisher; Josh Loucks; Seth Cohen; Andrea Woods
Subject: Re: Nice note from John Deutch

All

I'm seeing reports that a group of upset scientists are going to write their own rebuttal to our report. I suspect this will be outside of the public comment effort and designed to torpedo what we do in our responses. Do we simply say their report should have been submitted for formal consideration?

John C.

On Thu, Jul 31, 2025 at 10:10 AM Ross McKittrick <ross.mckittrick@gmail.com> wrote:
Much appreciated.

On Thu, Jul 31, 2025 at 10:11 AM Steven Koonin <steven.koonin@gmail.com> wrote:

From: John M Deutch <jmd@mit.edu>
Date: July 31, 2025 at 06:29:06 MDT
To: Steven Koonin <koonin@stanford.edu>
Subject: Critical Review

Steve,

I am reading your critical review of GHGs and find it very well done and informative. I anticipate the report near universal criticism, but not from me. I am reading the report carefully and I am in general agreement.

I congratulate you and your collaborators for this much needed assessment.

John

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Sent: Thursday, July 31, 2025 12:11 PM
To: John Christy
Cc: Ross McKittrick; Steven Koonin; Roy W. Spencer; Travis Fisher; Josh Loucks; Seth Cohen; Andrea Woods
Subject: Re: Nice note from John Deutch

They're going to do what they're going to do, and they all have TDS and hence won't trust the 'system'

On Thu, Jul 31, 2025 at 8:59 AM John Christy <climateman60@gmail.com> wrote:
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John

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To help protect
your privacy,
Microsoft Office
prevented
automatic
download of this
picture from the
Internet.

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To: Steven Koonin
Cc: Ross McKittrick; Judith Curry; Roy W. Spencer; Travis Fisher; Josh Loucks; Seth Cohen; Andrea Woods
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So ... if they don't submit their report, we could do it on their behalf?

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On Thu, Jul 31, 2025 at 11:14 AM Steven Koonin <steven.koonin@gmail.com> wrote:
This is good. We want that kind of dialogue.

Assuming they're credible, I think our response depends on timing.

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From: Ross McKittrick <ross.mckitrick@gmail.com>
Sent: Thursday, July 31, 2025 12:35 PM
To: Steven Koonin
Cc: John Christy; Judith Curry; Roy W. Spencer; Travis Fisher; Josh Loucks; Seth Cohen; Andrea Woods
Subject: Re: Nice note from John Deutch

Yes we should deal with it either way, however our workload needs to be manageable in the coming months. For my part I'm rather drained from the work thus far and I am not willing to spend the rest of the summer in a 24/7 rapid reaction mode. The advantage of the docket approach is that we can deal with everything in an orderly way. Some of the responses may require us to read a lot of new material, or re-read a lot of old material, and that takes time.

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From: Judith Curry <curry.judith@gmail.com>
Sent: Thursday, July 31, 2025 12:36 PM
To: Ross McKittrick
Cc: Steven Koonin; John Christy; Roy W. Spencer; Travis Fisher; Josh Loucks; Seth Cohen; Andrea Woods
Subject: Re: Nice note from John Deutch

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Reno, NV USA
curry.judith@cfanclimate.com | +1.404.803.2012
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From: John Christy <climateman60@gmail.com>
Sent: Thursday, July 31, 2025 12:40 PM
To: Judith Curry
Cc: Ross McKittrick; Steven Koonin; Roy W. Spencer; Travis Fisher; Josh Loucks; Seth Cohen; Andrea Woods
Subject: Re: Nice note from John Deutch

My summer ends in two weeks and I've been given 2 classes to teach, one a new preparation, as well as other duties. My time will need to be judiciously spent. Are there other scientists we could enlist, or are we it?

John C.

On Thu, Jul 31, 2025 at 11:36 AM Judith Curry <curry.judith@gmail.com> wrote:
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your privacy,
Outlook prevented
automatic
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From: Roy Spencer <roywspencer@hotmail.com>
Sent: Thursday, July 31, 2025 2:27 PM
To: Steven Koonin; John Christy
Cc: Ross McKittrick; Judith Curry; Travis Fisher; Josh Loucks; Seth Cohen; Andrea Woods
Subject: Re: Nice note from John Deutch

I predict that this will be the way they continue to make the debate adjudicated by the mainstream media, because what's the only way we lose. This is why Steve's idea that we don't allow the media to play that role is a good one.
-Roy

From: Steven Koonin <steven.koonin@gmail.com>
Sent: Thursday, July 31, 2025 11:23 AM
To: John Christy <climateman60@gmail.com>
Cc: Ross McKittrick <ross.mckittrick@gmail.com>; Judith Curry <curry.judith@gmail.com>; Roy W. Spencer <roywspencer@hotmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>; Josh Loucks <loucksj14@gmail.com>; Seth Cohen <seth.cohen@hq.doe.gov>; Andrea Woods <andrea.woods@hq.doe.gov>
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From: Judith Curry [curry.judith@gmail.com]
Sent: 4/19/2025 3:14:24 PM
To: Ross McKittrick [ross.mckittrick@gmail.com]
CC: Roy Spencer [roywspencer@hotmail.com]; Travis Fisher [travis.scott.fisher@gmail.com]; John Christy [climatemanager60@gmail.com]; Steven Koonin [steven.koonin@gmail.com]
Subject: Re: Our authorship vs. that of the EPA's 2009 EF TSD

The issues that Ross raises are important, and I think that the deadline needs to be pushed back for a variety of reasons.

Apart from the issues raised by Ross in terms of a lack of formal designation of responsibility and statement of task (an official letter or something) and arrangement for compensation (I understand why this one would take awhile), I don't want my name associated with a document that hasn't been carefully vetted and agreed upon by all of the authors.

I will continue to work on this over the next two weeks, but I agree that the status of any document we produce should be regarded as draft work product and not distributed outside of the DOE leadership, until these issues are resolved

On Sat, Apr 19, 2025 at 7:23 AM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

Travis, At this point I do not authorize you to share any work product I have contributed with any other group inside or outside the US government. At this point I am sharing notes with some colleagues on some topics of mutual interest in my private capacity as a non-US citizen. I am not a DoE employee or contractor and this is not a DoE work product.

I realize that people on your end have a use in mind for this material although so far no one has done us the courtesy of offering a clear explanation of exactly what we are being asked to do. I can't be expected to attach any more importance to contributing to the project than you guys attach to me being involved in it. So far, other than the original phone call recruiting me no one on your end has indicated you perceive any tangible value to having me involved. Providing a TSD to support a reassessment of the EF is very demanding and puts authors on the hook for a long time into the future to deal with what will be a lot of criticism. The apparent deadline for our contribution is rapidly approaching. Unless we have reached in writing an arrangement that provides suitable compensation for my time (and in my case any necessary work visas) I will have to withdraw all the material I've circulated and leave the project to others.

Cheers,
Ross

On Sat, Apr 19, 2025 at 7:12 AM Roy Spencer <roywspencer@hotmail.com> wrote:

All:

I spent a considerable amount of time last year reading/annotating/categorizing the December 7, 2009 Technical Support Document (TSD) for the CO2 Endangerment Finding. It is heavily referenced and undoubtedly involved years of work by a marching army of experts (guided, no doubt, by lawyers).

That document claimed to have 31 EPA authors, and 12 government expert reviewers. Attached is a spreadsheet with the backgrounds of each of those authors/reviewers.

Based upon their credentials, I would argue only one (Gavin Schmidt, an expert reviewer) had expertise directly relevant to the writing of the most important scientific claims in the document.

Arguably, *none of the EPA authors had the required expertise*. Many were new graduates in fields like geography. They then got promoted to management positions within the EPA.

It is for this reason that I now believe that most of the 2009 TSD was ghost-written, probably by more-expert volunteers and contractors to the two companies supporting the document preparation: Eastern Research Group, and Stratus Consulting.

This was no doubt a multi-million-dollar effort. Probably over \$10 Million.

About all I can hope is that what we write will provide sufficient "reasonable scientific doubt" regarding the science claims in the 2009 TSD, based upon almost 2 decades of new science, to call into question the original reasoning for the EPA Administrator's decision that CO2 presents a threat to human health and welfare.

It sounds like the lawyers involved believe they can win this fight without the science (lawyers and judges hate dealing with science).

But if the science argument is decided upon by a vote, or by the number of published citations, we lose the science argument.

-Roy

From: Travis Fisher

Sent: Friday, April 18, 2025 9:03 PM

To: Judith Curry

Cc: Ross McKittrick; John Christy; Roy Spencer; Steven Koonin

Subject: Re: I'll need help: 10 sections to go

Thanks so much, Judy!

Great questions. I don't think anyone has taken on the "air pollutant" issue. Please feel free to tackle it if you like!

Regarding the regulation in question, I've been told this summary of the science will be published as a technical support document relevant to a new proposed rule on tailpipe emissions standards for motor vehicles. I don't know whether that means all motor vehicles or just light- and medium-duty vehicles. It might be helpful to differentiate GHG emissions from the different classes to give the EPA flexibility in that regard.

The previous administration combined the rules for GHGs and criteria pollutants into a "multi-pollutant" rule, and I don't have any information on how this administration will package the different emissions standards. The exact charge for you all is to provide an update on the science relevant to the EPA's endangerment determination with respect to GHGs. As I understand the assignment, the scope is only GHGs, not criteria pollutants.

Keep the questions coming! I can run them up the chain if I don't know the answers, and I am happy to relay any questions you all have to the relevant folks at DOE or other agencies.

For your awareness, I was asked to share the table of contents with the EPA team this evening, which I did (the April 18 version), with the understanding that it is a one-way street (me informing them of your work so they know what's coming, not them sending feedback or micro-managing it). As I assured Steve in the early

stages of this work, scientific integrity is paramount, and I will do everything in my power to preserve every word of the document as you all write it. In fact, the EPA team asked that the document be DOE-branded, meaning our true audience is the Secretary of Energy, and he emphasized to me that he wants nothing but science. In other words, the only compromise you have to make in how this is written is among yourselves, not between you all and policymakers, lawyers, or economists.

Thanks again for lending your expertise to this effort, all of you.

Best,
Travis

On Fri, Apr 18, 2025 at 8:46 PM Judith Curry <curry.judith@gmail.com> wrote:

I have a lot of material already written that should be relevant. I have a draft of the sea level rise section completed, am sending this to my assistant to format, will upload monday.

Roy, let me know if there are sections you can't complete, i may have some text that is already written

On Fri, Apr 18, 2025 at 3:06 PM Travis Fisher <travis.scott.fisher@gmail.com> wrote:

Good afternoon,

I'm happy to report that I just talked with Judy, and she accepted the mission (in case you're wondering, the vetting issue was a mishap). This is great news because the Secretary wanted all of you to be able to contribute.

Let's make sure to include Judy in all of our correspondence from now on. The documents should be available here: https://www.dropbox.com/sc/fo/wahx6lpwzu33m5vyri8x/ANTU1qAQJ-zXCFzP_gsJcOs?rlkey=1l3zqj9v46e1t5f4ywwxq7p8c&c=1&dl=0. Please let us know if you don't have access.

Best,
Travis

On Fri, Apr 18, 2025 at 4:59 PM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

Thanks John. The quote from Mauritsen and Roeckner is a great addition.

I find the figure hard to follow, whereas the quote makes the point very clearly, in their own words.

On Fri, Apr 18, 2025 at 4:55 PM John Christy <climateman60@gmail.com> wrote:

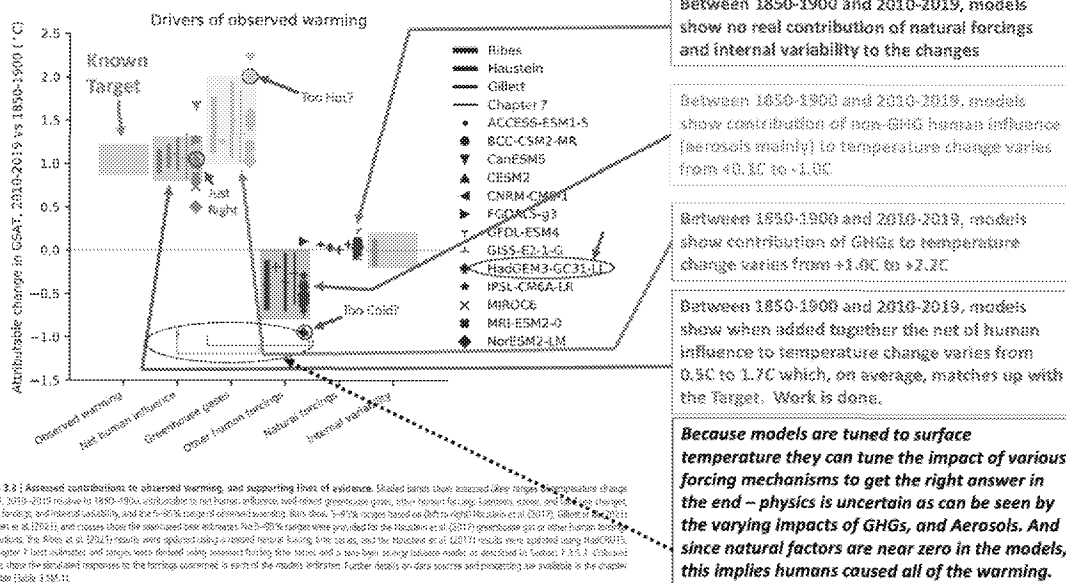
Ross

I've never been successful with dropbox and my record is still intact.

Attached is 1.6.2 to which I added a paragraph.

Also attached is a chart I annotated from AR6. I think this story demonstrates modelers are just playing with tuning parameters. Is there some way to use this information here (not necessarily in this format)?

John C.



On Fri, Apr 18, 2025 at 3:32 PM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

I've uploaded a new version of Section 2.2 to your folder. It includes the earlier material quoting all the relevant IPCC and NCA17 stuff and adds some external source information I found. Still needs a brief summary. Others may have more to add.

On Fri, Apr 18, 2025 at 3:05 PM Roy Spencer <roywspencer@hotmail.com> wrote:

Ross:

Let me look early in the morning to see which ones I feel like I can knock out the fastest. Our "guidance" has been to start from "scratch", while relying on preexisting materials where it helps. I think I know why we've been told this, but it's not my place to say.

- Roy

Sent from my Verizon, Samsung Galaxy smartphone

----- Original message -----

From: Ross McKittrick <ross.mckittrick@gmail.com>

Date: 4/18/25 10:49 AM (GMT-06:00)

To: Roy Spencer <roywspencer@hotmail.com>

Cc: Travis Fisher <travis.scott.fisher@gmail.com>, Steven Koonin <steven.koonin@gmail.com>, John Christy <climateman60@gmail.com>

Subject: Re: I'll need help: 10 sections to go

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Cc: Travis Fisher <travis.scott.fisher@gmail.com>; steven.koonin@gmail.com; roywspencer@hotmail.com

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John C.

Sent from my iPhone

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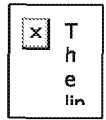
Best,
Travis

<DE.memo.outline.Apr.11.[RM].docx>

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Judith Curry, President
CFAN - Climate Forecast Applications Network
Reno, NV USA
curry.judith@cfanclimate.com | +1.404.803.2012
<http://www.cfanclimate.net>



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From: Travis Fisher <travis.scott.fisher@gmail.com>
Sent: Saturday, April 19, 2025 11:54 AM
To: Judith Curry; Ross McKittrick; Roy Spencer
Cc: John Christy; Steven Koonin
Subject: Re: Our authorship vs. that of the EPA's 2009 EF TSD

Roy, Ross, and Judy, it sounds like we should have a conference call as soon as possible to discuss the important issues you have raised. Please let me know your availability. I will start the bidding at 1 p.m. ET today.

John and Steve, you should feel free to join if you like, although I understand Steve is traveling in a distant time zone.

On Sat, Apr 19, 2025 at 11:14 AM Judith Curry <curry.judith@gmail.com> wrote:

The issues that Ross raises are important, and I think that the deadline needs to be pushed back for a variety of reasons.

Apart from the issues raised by Ross in terms of a lack of formal designation of responsibility and statement of task (an official letter or something) and arrangement for compensation (I understand why this one would take awhile), I don't want my name associated with a document that hasn't been carefully vetted and agreed upon by all of the authors.

I will continue to work on this over the next two weeks, but I agree that the status of any document we produce should be regarded as draft work product and not distributed outside of the DOE leadership, until these issues are resolved

On Sat, Apr 19, 2025 at 7:23 AM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

Travis, At this point I do not authorize you to share any work product I have contributed with any other group inside or outside the US government. At this point I am sharing notes with some colleagues on some topics of mutual interest in my private capacity as a non-US citizen. I am not a DoE employee or contractor and this is not a DoE work product.

I realize that people on your end have a use in mind for this material although so far no one has done us the courtesy of offering a clear explanation of exactly what we are being asked to do. I can't be expected to attach any more importance to contributing to the project than you guys attach to me being involved in it. So far, other than the original phone call recruiting me no one on your end has indicated you perceive any tangible value to having me involved. Providing a TSD to support a reassessment of the EF is very demanding and puts authors on the hook for a long time into the future to deal with what will be a lot of criticism. The apparent deadline for our contribution is rapidly approaching. Unless we have reached in writing an arrangement that provides suitable compensation for my time (and in my case any necessary work visas) I will have to withdraw all the material I've circulated and leave the project to others.

Cheers,
Ross

On Sat, Apr 19, 2025 at 7:12 AM Roy Spencer <roywspencer@hotmail.com> wrote:

All:

I spent a considerable amount of time last year reading/annotating/categorizing the December 7, 2009 Technical Support Document (TSD) for the CO2 Endangerment Finding. It is heavily referenced and undoubtedly involved years of work by a marching army of experts (guided, no doubt, by lawyers).

That document claimed to have 31 EPA authors, and 12 government expert reviewers. Attached is a spreadsheet with the backgrounds of each of those authors/reviewers.

Based upon their credentials, I would argue only one (Gavin Schmidt, an expert reviewer) had expertise directly relevant to the writing of the most important scientific claims in the document.

Arguably, *none of the EPA authors had the required expertise*. Many were new graduates in fields like geography. They then got promoted to management positions within the EPA.

It is for this reason that I now believe that most of the 2009 TSD was ghost-written, probably by more-expert volunteers and contractors to the two companies supporting the document preparation: Eastern Research Group, and Stratus Consulting.

This was no doubt a multi-million-dollar effort. Probably over \$10 Million.

About all I can hope is that what we write will provide sufficient "reasonable scientific doubt" regarding the science claims in the 2009 TSD, based upon almost 2 decades of new science, to call into question the original reasoning for the EPA Administrator's decision that CO2 presents a threat to human health and welfare.

It sounds like the lawyers involved believe they can win this fight without the science (lawyers and judges hate dealing with science).

But if the science argument is decided upon by a vote, or by the number of published citations, we lose the science argument.

-Roy

From: Travis Fisher
Sent: Friday, April 18, 2025 9:03 PM
To: Judith Curry
Cc: Ross McKittrick; John Christy; Roy Spencer; Steven Koonin
Subject: Re: I'll need help: 10 sections to go

Thanks so much, Judy!

Great questions. I don't think anyone has taken on the "air pollutant" issue. Please feel free to tackle it if you like!

Regarding the regulation in question, I've been told this summary of the science will be published as a technical support document relevant to a new proposed rule on tailpipe emissions standards for motor vehicles. I don't know whether that means all motor vehicles or just light- and medium-duty vehicles. It might be helpful to differentiate GHG emissions from the different classes to give the EPA flexibility in that regard.

The previous administration combined the rules for GHGs and criteria pollutants into a "multi-pollutant" rule, and I don't have any information on how this administration will package the different emissions standards. The exact charge for you all is to provide an update on the science relevant to the EPA's endangerment determination with respect to GHGs. As I understand the assignment, the scope is only GHGs, not criteria pollutants.

Keep the questions coming! I can run them up the chain if I don't know the answers, and I am happy to relay any questions you all have to the relevant folks at DOE or other agencies.

For your awareness, I was asked to share the table of contents with the EPA team this evening, which I did (the April 18 version), with the understanding that it is a one-way street (me informing them of your work so they know what's coming, not them sending feedback or micro-managing it). As I assured Steve in the early stages of this work, scientific integrity is paramount, and I will do everything in my power to preserve every word of the document as you all write it. In fact, the EPA team asked that the document be DOE-branded, meaning our true audience is the Secretary of Energy, and he emphasized to me that he wants nothing but science. In other words, the only compromise you have to make in how this is written is among yourselves, not between you all and policymakers, lawyers, or economists.

Thanks again for lending your expertise to this effort, all of you.

Best,
Travis

On Fri, Apr 18, 2025 at 8:46 PM Judith Curry <curry.judith@gmail.com> wrote:

I have a lot of material already written that should be relevant. I have a draft of the sea level rise section completed, am sending this to my assistant to format, will upload monday.

Roy, let me know if there are sections you can't complete, i may have some text that is already written

On Fri, Apr 18, 2025 at 3:06 PM Travis Fisher <travis.scott.fisher@gmail.com> wrote:

Good afternoon,

I'm happy to report that I just talked with Judy, and she accepted the mission (in case you're wondering, the vetting issue was a mishap). This is great news because the Secretary wanted all of you to be able to contribute.

Let's make sure to include Judy in all of our correspondence from now on. The documents should be available here: https://www.dropbox.com/scl/fo/wahx6lpwzu33m5vyrr8x/ANTU1qAQJ-zXCFzP_gsJcOs?rlkey=11z3qj9v46e1t5f4ywwxq7p8c&e=1&dl=0. Please let us know if you don't have access.

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Travis

On Fri, Apr 18, 2025 at 4:59 PM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

Thanks John. The quote from Mauritsen and Roeckner is a great addition.

I find the figure hard to follow, whereas the quote makes the point very clearly, in their own words.

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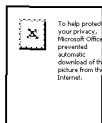
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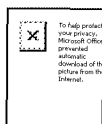
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Subject: Re: Our authorship vs. that of the EPA's 2009 EF TSD

Travis, At this point I do not authorize you to share any work product I have contributed with any other group inside or outside the US government. At this point I am sharing notes with some colleagues on some topics of mutual interest in my private capacity as a non-US citizen. I am not a DoE employee or contractor and this is not a DoE work product.

I realize that people on your end have a use in mind for this material although so far no one has done us the courtesy of offering a clear explanation of exactly what we are being asked to do. I can't be expected to attach any more importance to contributing to the project than you guys attach to me being involved in it. So far, other than the original phone call recruiting me no one on your end has indicated you perceive any tangible value to having me involved. Providing a TSD to support a reassessment of the EF is very demanding and puts authors on the hook for a long time into the future to deal with what will be a lot of criticism. The apparent deadline for our contribution is rapidly approaching. Unless we have reached in writing an arrangement that provides suitable compensation for my time (and in my case any necessary work visas) I will have to withdraw all the material I've circulated and leave the project to others.

Cheers,
Ross

On Sat, Apr 19, 2025 at 7:12 AM Roy Spencer <roywspencer@hotmail.com> wrote:
All:

I spent a considerable amount of time last year reading/annotating/categorizing the December 7, 2009 Technical Support Document (TSD) for the CO2 Endangerment Finding. It is heavily referenced and undoubtedly involved years of work by a marching army of experts (guided, no doubt, by lawyers).

That document claimed to have 31 EPA authors, and 12 government expert reviewers. Attached is a spreadsheet with the backgrounds of each of those authors/reviewers.

Based upon their credentials, I would argue only one (Gavin Schmidt, an expert reviewer) had expertise directly relevant to the writing of the most important scientific claims in the document.

Arguably, *none of the EPA authors had the required expertise*. Many were new graduates in fields like geography. They then got promoted to management positions within the EPA.

It is for this reason that I now believe that most of the 2009 TSD was ghost-written, probably by more-expert volunteers and contractors to the two companies supporting the document preparation: Eastern Research Group, and Stratus Consulting.

This was no doubt a multi-million-dollar effort. Probably over \$10 Million.

About all I can hope is that what we write will provide sufficient "reasonable scientific doubt" regarding the science claims in the 2009 TSD, based upon almost 2 decades of new science, to call into question the original reasoning for the EPA Administrator's decision that CO2 presents a threat to human health and welfare.

It sounds like the lawyers involved believe they can win this fight without the science (lawyers and judges hate dealing with science).

But if the science argument is decided upon by a vote, or by the number of published citations, we lose the science argument.

-Roy

From: Travis Fisher

Sent: Friday, April 18, 2025 9:03 PM

To: Judith Curry

Cc: Ross McKittrick; John Christy; Roy Spencer; Steven Koonin

Subject: Re: I'll need help: 10 sections to go

Thanks so much, Judy!

Great questions. I don't think anyone has taken on the "air pollutant" issue. Please feel free to tackle it if you like!

Regarding the regulation in question, I've been told this summary of the science will be published as a technical support document relevant to a new proposed rule on tailpipe emissions standards for motor vehicles. I don't know whether that means all motor vehicles or just light- and medium-duty vehicles. It might be helpful to differentiate GHG emissions from the different classes to give the EPA flexibility in that regard.

The previous administration combined the rules for GHGs and criteria pollutants into a "multi-pollutant" rule, and I don't have any information on how this administration will package the different emissions standards. The exact charge for you all is to provide an update on the science relevant to the EPA's endangerment determination with respect to GHGs. As I understand the assignment, the scope is only GHGs, not criteria pollutants.

Keep the questions coming! I can run them up the chain if I don't know the answers, and I am happy to relay any questions you all have to the relevant folks at DOE or other agencies.

For your awareness, I was asked to share the table of contents with the EPA team this evening, which I did (the April 18 version), with the understanding that it is a one-way street (me informing them of your work so they know what's coming, not them sending feedback or micro-managing it). As I assured Steve in the early stages of this work, scientific integrity is paramount, and I will do everything in my power to preserve every word of the document as you all write it. In fact, the EPA team asked that the document be DOE-branded, meaning our true audience is the Secretary of Energy, and he emphasized to me that he wants nothing but science. In other words, the only compromise you have to make in how this is written is among yourselves, not between you all and policymakers, lawyers, or economists.

Thanks again for lending your expertise to this effort, all of you.

Best,

Travis

On Fri, Apr 18, 2025 at 8:46 PM Judith Curry <curry.judith@gmail.com> wrote:

I have a lot of material already written that should be relevant. I have a draft of the sea level rise section completed, am sending this to my assistant to format, will upload monday.

Roy, let me know if there are sections you can't complete, i may have some text that is already written

On Fri, Apr 18, 2025 at 3:06 PM Travis Fisher <travis.scott.fisher@gmail.com> wrote:

Good afternoon,

I'm happy to report that I just talked with Judy, and she accepted the mission (in case you're wondering, the vetting issue was a mishap). This is great news because the Secretary wanted all of you to be able to contribute.

Let's make sure to include Judy in all of our correspondence from now on. The documents should be available here: https://www.dropbox.com/scl/fo/wahx6lpwzu33m5vyrr8x/ANTU1qAQJ-zXCFzP_gsJcOs?rlkey=11z3qj9v46e1t5f4ywwxq7p8c&e=1&dl=0. Please let us know if you don't have access.

Best,
Travis

On Fri, Apr 18, 2025 at 4:59 PM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

Thanks John. The quote from Mauritsen and Roeckner is a great addition.

I find the figure hard to follow, whereas the quote makes the point very clearly, in their own words.

On Fri, Apr 18, 2025 at 4:55 PM John Christy <climateman60@gmail.com> wrote:

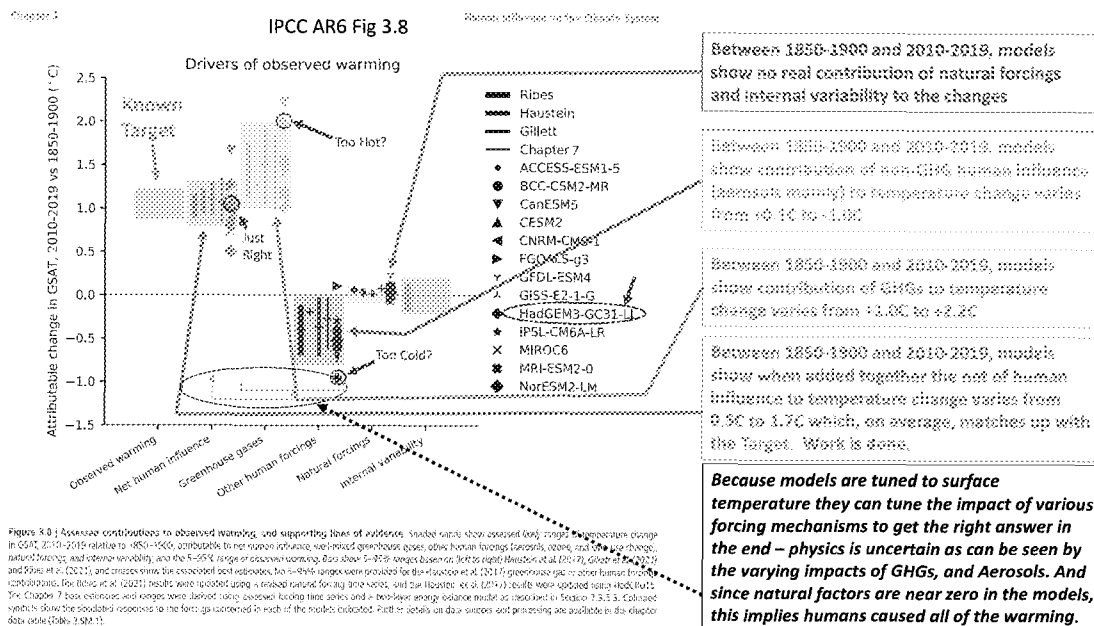
Ross

I've never been successful with dropbox and my record is still intact.

Attached is 1.6.2 to which I added a paragraph.

Also attached is a chart I annotated from AR6. I think this story demonstrates modelers are just playing with tuning parameters. Is there some way to use this information here (not necessarily in this format)?

John C.



On Fri, Apr 18, 2025 at 3:32 PM Ross McKittrick <ross.mckittrick@gmail.com> wrote:
I've uploaded a new version of Section 2.2 to your folder. It includes the earlier material quoting all the relevant IPCC and NCA17 stuff and adds some external source information I found. Still needs a brief summary. Others may have more to add.

On Fri, Apr 18, 2025 at 3:05 PM Roy Spencer <roywspencer@hotmail.com> wrote:
Ross:
Let me look early in the morning to see which ones I feel like I can knock out the fastest. Our "guidance" has been to start from "scratch", while relying on preexisting materials where it helps. I think I know why we've been told this, but it's not my place to say.
- Roy

Sent from my Verizon, Samsung Galaxy smartphone

----- Original message -----

From: Ross McKittrick <ross.mckittrick@gmail.com>
Date: 4/18/25 10:49 AM (GMT-06:00)
To: Roy Spencer <roywspencer@hotmail.com>
Cc: Travis Fisher <travis.scott.fisher@gmail.com>, Steven Koonin <steven.koonin@gmail.com>, John Christy <climateman60@gmail.com>
Subject: Re: I'll need help: 10 sections to go

Sorry Roy, I didn't mean to swamp you, I figured those were sections you already had in the can from previous work. Looking through my own folders I have some material I forgot I had written which I can repurpose. Can you send a list of the sections you are able to do, and the ones you would like to hand off for the time being?

Also to Travis' point we should look to having Judy help some of the sections. Travis, she can be reached via curry.judith@gmail.com

Ross

On Fri, Apr 18, 2025 at 7:40 AM Roy Spencer <roywspencer@hotmail.com> wrote:
All:

I don't see how I'm going to do the 10 more sections assigned to me (1.6.1 onward) in the time remaining. Feel free to jump in.

-Roy

From: Roy Spencer <roywspencer@hotmail.com>
Sent: Friday, April 18, 2025 6:34 AM
To: Ross McKittrick <ross.mckittrick@gmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>
Cc: Steven Koonin <steven.koonin@gmail.com>; John Christy <climateman60@gmail.com>
Subject: Section 1.4.3 attached

Ross:

I think we should combine sections 1.4.3 and 1.4.4 (attached) which I now call "The carbon cycle, emissions scenarios, and global greening".

I found that all of these need to be discussed together. Feel free to reword the section title.

-Roy

From: Roy Spencer <roywspencer@hotmail.com>
Sent: Thursday, April 17, 2025 6:17 AM
To: Ross McKittrick <ross.mckittrick@gmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>
Cc: Steven Koonin <steven.koonin@gmail.com>; John Christy <climateman60@gmail.com>
Subject: Section 1.4.2 Can climate models reproduce the recent past?

Attached. This is the minimum I think needs to be in this section. Of course, more could be added, but I think we need to stick to our strongest arguments, given the limited time available.

-Roy

From: Roy Spencer <roywspencer@hotmail.com>
Sent: Wednesday, April 16, 2025 7:16 AM
To: Ross McKittrick <ross.mckittrick@gmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>
Cc: Steven Koonin <steven.koonin@gmail.com>; John Christy <climateman60@gmail.com>
Subject: Some Spencer inputs

I took it upon myself to write a preamble in **Section 1.3 Drivers of climate change** (attached), which seemed necessary to introduce some basic concepts.

Also attached are my initial submissions for **1.3.2** and **1.3.3**.

NO references added yet.

One of the things I believe we need to watch out for is *neglecting to come to conclusions along the way*... There is a tendency to get mired in the technical details without getting around to saying what each section might mean in eventual policy decisions related to the Endangerment Finding. In my experience, it is not possible to dumb-down this stuff too much. I suggest some sort of "Summary Boxes" with 1-2 simplified statements highlighting a main conclusion of each section that would have policy relevance.

-Roy

From: Ross McKittrick <ross.mckittrick@gmail.com>

Sent: Monday, April 14, 2025 1:37 PM

To: Travis Fisher <travis.scott.fisher@gmail.com>

Cc: Steven Koonin <steven.koonin@gmail.com>; John Christy <climateman60@gmail.com>;
roywspencer@hotmail.com <roywspencer@hotmail.com>

Subject: Re: Kickoff

Hi Travis

We developed the outline a bit further and assigned sections out yesterday. We'll keep you cc'd going forward.

Here is a Dropbox link that contains the current outline (also attached) which indicates who is working on each section

https://www.dropbox.com/scl/fo/wahx6lpwzu33m5vyrr8x/ANTU1qAQJ-zXCFzP_gsJcOs?rlkey=l1z3qj9v46e1t5f4ywwxq7p8c&dl=0

The link should give you all editing privileges.

I put folders in there for each of us. If the use of that Dropbox (which is on my own account) is acceptable for this project then we can share our work using it. Otherwise once we have an official Dropbox created we can transfer the material over to it.

Do you think it would be helpful to have a section specifically addressing the question of whether CO2 is a pollutant like CO, NOx, SOx, PM, etc.? If you want to add topics or suggest changes please do, the earlier the better as we begin filling out the contents.

Cheers,

Ross

On Mon, Apr 14, 2025 at 2:12 PM Travis Fisher <travis.scott.fisher@gmail.com> wrote:

This is an excellent start! Can we move forward by iterating with this document for now? Please feel free to add whatever material you like, and I can collate if there are any simultaneous changes. I will leave the substance to you all because I view my role as a facilitator rather than a contributor, but please let me know how I can be most helpful.

Steve is correct that this document should be clear and understandable for non-experts. My understanding is that it should also be sufficiently technical and comprehensive to inform policymakers on all relevant aspects of the science.

One area I can help with might be targeting your work for the very brief window we have open at the moment. I am including a few lines verbatim below from key documents to highlight the areas of inquiry that are most relevant to the policymaking process. Of course, you all should make your own judgments about what to include versus what to leave out.

Here is a key section of the Clean Air Act, 202(a)(1): "The Administrator shall by regulation prescribe (and from time to time revise) in accordance with the provisions of this section, standards applicable to the emission of any air pollutant from any class or classes of new motor vehicles or new motor vehicle engines, which in his judgment cause, or contribute to, air pollution which may reasonably be anticipated to endanger public health or welfare. Such standards shall be applicable to such vehicles and engines for their useful life (as determined under subsection (d), relating to useful life of vehicles for purposes of certification), whether such vehicles and engines are designed as complete systems or incorporate devices to prevent or control such pollution."

Section 202 can be found [here](#).

Here is another key section of the Clean Air Act, section 302(g): "The term 'air pollutant' means any air pollution agent or combination of such agents, including any physical, chemical, biological, radioactive (including source material, special nuclear material, and byproduct material) substance or matter which is emitted into or otherwise enters the ambient air. Such term includes any precursors to the formation of any air pollutant, to the extent the Administrator has identified such precursor or precursors for the particular purpose for which the term 'air pollutant' is used."

A threshold question raised in Justice Scalia's dissent in *Mass v. EPA* (which can be found [here](#)) is whether CO2 falls under the definition of an "air pollutant" under the Clean Air Act. The majority in *Mass v. EPA* found that *any* compound emitted into the ambient air fits the definition of "air pollutant," leading to a colorful footnote in the Scalia dissent ("It follows that everything airborne, from Frisbees to flatulence, qualifies as an 'air pollutant.' This reading of the statute defies common sense."). A scientific interpretation of this definition could be very helpful.

The next section in the statute is 302(h), which defines effects on welfare: "All language referring to effects on welfare includes, but is not limited to, effects on soils, water, crops, vegetation, manmade materials, animals, wildlife, weather, visibility, and climate, damage to and deterioration of property, and hazards to transportation, as well as effects on economic values and on personal comfort and well-being, whether caused by transformation, conversion, or combination with other air pollutants." Positive impacts, including fertilization effects and beneficial warming, seem to be within scope here.

Section 302 can be found [here](#).

As you all develop the draft, I encourage you to include as many citations to published materials as possible (links would work fine as placeholders). I have found this works better under a tight timeline than going back and looking for sources later. Please also feel free to task me with any research help you might need.

Best,
Travis

On Fri, Apr 11, 2025 at 8:10 PM Steven Koonin <steven.koonin@gmail.com> wrote:

I assume we're writing for non-experts. If so, some educating beyond the root questions is in order (it always helps if people feel smarter after reading).

So I've taken Ross' material, added some broader context, and cast it into the forcing/response/impact syllogism that most non-experts seem to get. The result is attached.

I think we can deal with the differences relative to 2009 in an appendix.

SEK

From: John Christy <climateman60@gmail.com>

Sent: Friday, April 11, 2025 6:34 PM

To: Ross McKittrick <ross.mckittrick@gmail.com>

Cc: Travis Fisher <travis.scott.fisher@gmail.com>; steven.koonin@gmail.com; roywspencer@hotmail.com

Subject: Re: Kickoff

Excellent list Ross. Wildfires are a significant topic to be addressed.

John C.

Sent from my iPhone

On Apr 11, 2025, at 4:05 PM, Ross McKittrick <ross.mckittrick@gmail.com> wrote:

The attached represents my summary of the most questions needing to be answered, which I think this group is capable of answering in the next couple of weeks. Probably lots of material already in hand.

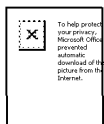
On Fri, Apr 11, 2025 at 4:24 PM Travis Fisher <travis.scott.fisher@gmail.com> wrote:

Gentlemen,

I can't thank you enough for taking this on under such a tight timeline. Let's use this thread to exchange information, links, etc., and as we move forward, I'll see about a document-sharing platform and a shared document to work on simultaneously.

Best,
Travis

<DE.memo.outline.Apr.11.[RM].docx>



Judith Curry, President
CFAN - Climate Forecast Applications Network
Reno, NV USA
curry.judith@cfanclimate.com | +1.404.803.2012
<http://www.cfanclimate.net>

11

From: John Christy [climateman60@gmail.com]
Sent: 8/23/2025 8:13:30 PM
To: Steve Koonin [steven.koonin@gmail.com]
CC: Judith Curry [curry.judith@gmail.com]; Ross McKittrick [ross.mckittrick@gmail.com]; Roy Spencer [roywspencer@hotmail.com]
Subject: Re: our zoom just now
Attachments: DoE_Public_Comments_JRC_250823.xlsx; Untitled attachment 02147.htm

All

I've gone through about 50 comments. Vast majority are complaints or kudos with no specific actions to take. One, however, (#0182) did claim that section 10.3 is wrong about heat mortality (saying we used old publications) and that heat mortality is increasing offering several recent citations.

Attached is my feeble attempt to keep track of these. However, sometimes when I return to the comment page, the comments have been re-configured, making it difficult to track where I am. Is there a way to re-order the comments, say in numerical order?

John C.

John Christy
Director, Earth System Science Center
Professor, Atmos and Earth Science
Alabama State Climatologist
The University of Alabama in Huntsville
climateman60@gmail.com

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NS = No Specifics

Is convinced extreme weather is getting worse due to humans. NS

Kudos to CWG. Many comments on earth's climate history. NS

"Appalled". Advises global values of increasing extremes (but did not contradict US extremes)

Water vapor enhancement issues. NS

Suggests Dark Matter (Dark Energy) may be important. NS

Kudos to CWG

Kudos to CWG. Comments on radiation and CO2 v Temp causality

"Cherry-picking, non publishing climate scientists paid by fossil fuel interests", NS

Advises checking US Temperatures for negating CO2 v Temp relationship. NS

Kudos to CWG

GMST is meaningless - ref. C. Essex

PDF document. Complains of process, indicating the Secretary is at fault. NS
Complaints, NS

PDF. Misrepresenting ECS, Solar Variability, extreme events, sea level rise, scenarios, UHI, etc. No counter

Kudos to CWG

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Links to reports that scientists claim they were misused in CWG. NS

Very Long, Advises geoengineering. NS

"citations aren't real, clear use of AI". NS

Kudos to CWG

Kudos to CWG

Advise deferring to "Global Expert Consensus" or IPCC. NS

Kudos to CWG

Suspects AI likely did the report. Claims error in citation Lee, S., Byrne, et al 2024. Wrong paper.

Complaints, NS

Kudos to CWG, mitigation must be stopped

Kudos to CWG

Complaints, NS, Christy and Spencer use "fake data"

Complaints, NS

Complaints that extreme weather section is "misleading". Needs "viewpoint diversity". NS

Advises citing statistics for last 20 years on health impacts to capture very recent trends.

"laughable". NS

Claims of extreme weather are "categorically false". CO2 is poisonous. NS

Complaints, NS

"Child's statement of lies." NS

Claims heat mortality section based on old publications. Provides others that say heat mortality is increasing. Kudos to CWG. Notes that Grok's analysis of the report is misleading.

Complaints, NS

Complaints, NS

"Blatently false information". NS

Misleading comments on McKinnons paper, advises stating background is warming in PacNw

Expectant mom wants to save her child from climate change. NS

Complaints, NS

Sec 6.2 - wants slope and p-value for hurricane trends

"foolish and hubristic". NS

^evidence offered.

sing. Sec 10.3

On Aug 22, 2025, at 3:24 PM, Steven Koonin <steven.koonin@gmail.com> wrote:

That zoom was a bit of a bust. No meaningful information conveyed to us, just "Wait until Monday's meeting."

I'm concerned we're going to hear "full stop" from the lawyers. That would not be good.

SEK

From: Judith Curry <curry.judith@gmail.com>
Sent: Saturday, April 19, 2025 4:22 PM
To: Ross McKittrick
Cc: Steven Koonin; Travis Fisher; Roy Spencer; John Christy
Subject: Re: outline for a slimmed down report

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From: Judith Curry [curry.judith@gmail.com]
Sent: 4/19/2025 11:10:52 PM
To: Steven Koonin [steven.koonin@gmail.com]
CC: Ross McKittrick [ross.mckittrick@gmail.com]; Travis Fisher [travis.scott.fisher@gmail.com]; Roy Spencer [roywspencer@hotmail.com]; John Christy [climateman60@gmail.com]
Subject: Re: outline for a slimmed down report

I have done heat/cold mortality (working on foot notes, will post shortly

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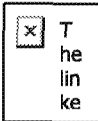
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Sent: Saturday, April 19, 2025 7:12 PM
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I can put 10 together quickly, global greening, I have all the notes.

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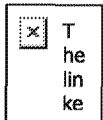
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CC: Roy Spencer [roywspencer@hotmail.com]; Ross McKittrick [ross.mckittrick@gmail.com]; John Christy [climatemanager60@gmail.com]
Subject: Re: page count
Attachments: Factcheck_Trump's climate report includes more than 100 false or misleading claims.docx

oops i sent the wrong version attached is cleaned up .doc

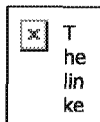
On Thu, Aug 14, 2025 at 4:02 PM Steven Koonin <steven.koonin@gmail.com> wrote:

By my count of the opening graphic, 63 of the 112 pages (or 56%) are “white”, meaning no criticism offered. Considering the intensity of the scrutiny, the comments that call for more context, and the nit-picking nature of some (e.g., on pg 17 of the report, we’re criticized for saying “about 850 Gt” rather than the more precise up-to-date number of 877 Gt), I’d say we’re in pretty good shape.

Unless someone has done so already, I can write to Soon and Connolly and ask them how they’d respond to the TSI criticisms.

SEK

--



Judith Curry, President
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Factcheck: Trump's climate report includes more than 100 false or misleading claims

By Ayesha Tandon, Leo Hickman, Cecilia Keating and Robert McSweeney Design by Tom
Prater

Part I: Direct human influence on ecosystems and the climate

1 Carbon dioxide as a pollutant

Page 2

MISLEADING

The growing amount of CO2 in the atmosphere directly influences the Earth system by promoting plant growth (global greening), thereby enhancing agricultural yields, and by neutralising ocean alkalinity.

I see two main problems with this (very old) argument. The direct benefits of CO2 are widely acknowledged and nothing new. But we know that elevated CO2 leads to climate changes and so the question is whether the CO2 benefits are big enough to offset the climate losses. Their report does not address the net effects, which many studies have shown are negative, even for the US. The numbers they cite for direct effects of CO2 are mainly from co2science.org, which is not a reputable source. Their summaries are not peer reviewed and include many studies of pots in greenhouses which are known to be biased. The numbers cited in the report are more than 2x what the best literature shows, such as in Ainsworth & Long (2021).

Part I: Direct human influence on ecosystems and the climate

1 Carbon dioxide as a pollutant

Page 2

MISLEADING

The growing amount of CO2 in the atmosphere directly influences the Earth system by promoting plant growth (global greening), thereby enhancing agricultural yields, and by neutralising ocean alkalinity

Anonymous

This ignores other effects of rising CO2 concentrations, i.e.: on climate. It is also failing to mention that increased CO2 can reduce the nutrient density of some crops.

2.1 CO2 as a contributor to global greening

Page 3

FALSE

While plant models predict increased photosynthesis in response to rising CO2, Haverd et al. (2020) reported a CO2 fertilisation rate much larger than model predictions. That is, CO2 fertilisation had driven an increase in observed global photosynthesis by 30% since 1900, versus 17% predicted by plant models. If true it would indicate that global models of the socioeconomic impacts of rising CO2 have understated the benefits to crops and agriculture.

Dr Delphine Deryng, lead author, IPCC AR6

The paper by Haverd et al. focuses on natural ecosystems, not crops. So whilst the findings that CO2 fertilisation effects on global greening makes a larger share relative to other factors, the results are not directly transferable to the socio-economic impacts of rising CO2 on agriculture. Rising CO2 contributes to higher radiative forcing which increases global mean temperature and accelerates the global water cycle, causing increases in the severity and frequency of extreme weather events (e.g. droughts, heat- stress and wildfires), particularly threatening crop yields and production

2.1 CO2 as a contributor to global greening

Page 3

MISLEADING

The growing CO2 concentration in the atmosphere has the important positive effect of promoting plant growth by enhancing photosynthesis and improving water use efficiency.

Anonymous

Promoting plant growth is not always positive, because some species benefit more than others, which creates risks to biodiversity. For example, in tropical forests, elevated CO2 promotes the growth of lianas, which are parasites that threaten trees. Also increased CO2 fertilisation is playing a role in disrupting grassland and savannah ecosystems by promoting tree and shrub growth ("woody encroachment").

2.1 CO2 as a contributor to global greening

Page 3

FALSE

Section 2.1.1

Anonymous

The following section cites papers that are, in fact, showing evidence for other drivers of change, e.g. page 14 line 34 says "Piao et al. (2020) noted that greening was even observable in the Arctic", but Piao et al (2020) actually show that warming is the dominant driver of greening in the Arctic, not CO2 fertilisation (see figure 4 and associated text). Also the authors of the DoE report contradict their own statement two paragraphs later by saying: "Chen et al. (2019) show that in China and India much of it is driven by land management changes."

2 Direct impacts of CO2 on the environment

Page 3

MISLEADING

Piao et al. (2020) and Chen et al. (2024) report that the greening trend continues with no evidence of slowdown.

Anonymous

The DoE authors fail to mention another study which shows the opposite, that greening was reversed around the year 2000 over 90% of the global vegetated area.

2.1 CO2 as a contributor to global greening

Pages 14-17

MISLEADING

Section 2.1

Dr David Crisp, retired atmospheric physicist

Chapters 2 and 9 assert that CO2 fertilisation will increase plant growth and crop yields. The proposed benefits of CO2 fertilisation are not realised in this set of DGVMs because this is only one of several mechanisms that control plant growth. As any farmer knows, plant growth is rarely limited by the abundance of the most abundant nutrient. It is usually limited by the abundance of the least abundant nutrient. While increased CO2 can accelerate plant growth in carefully controlled laboratory conditions, this rarely happens in nature or in large-scale agriculture. There, plant growth is usually limited by water, nitrogen, phosphorus, sunlight or temperature. These models include all of those effects. The range of outputs produced by the models reflects uncertainties in the relative roles of these processes and their potential evolution with climate change. This behaviour should foster serious concern (doubt) about the potential benefits of CO2 fertilisation in a changing climate. There is no discussion of this here or in chapters 2.1 or 9.

Quote given to Carbon Brief

2.1 CO2 as a contributor to global greening

Page 4

MISLEADING

Had atmospheric CO2 levels continued declining, plant growth would have declined and eventually ceased. Below 180ppm, the growth rates of many C3 species are reduced 40-60% relative to 350ppm (Gerhart and Ward (2010)) and growth has stopped altogether under experimental conditions of 60-140ppm CO2. Some C4 plants are still able to grow at levels even as low as 10ppm, albeit very slowly (Gerhart and Ward (2010)).

Prof Joy Ward, provost and executive vice president, Case Western Reserve University

”Ward, however, told WIRED in an emailed statement that her experiments were conducted under ‘highly controlled growth conditions’ to create a ‘mechanistic understanding’ of CO2, and that climate change can cause a host of impacts on plants not accounted for in her study. ‘With rising CO2 in natural ecosystems, plants may experience higher heat loads, extreme weather events such as droughts and floods and reduced pollinators – which can have severe net negative effects on plant growth and crop yields,’ she says. ‘Furthermore, our studies indicate that major disruptions in plant development such as flowering time can occur in direct response to rising CO2, which were not mentioned in the report.’”

2.1 CO2 as a contributor to global greening

Page 4

FALSE

Piao et al. (2020) and Chen et al. (2024) report that the greening trend continues with no evidence of slowdown, and CO2 fertilisation remains the dominant driver.

Dr Delphine Deryng, lead author, IPCC AR6 WG2

Chen et al (2024) does not back up this statement. In the abstract, the author concluded that greening, whilst still increasing, has slowed down: "Our study highlighted that drought trend did not necessarily trigger vegetation browning, but slowed down the rate of greening." Piao et al. (2019) looked at the driver of

global greening. They did not look at whether trends in global greening are rising or decreasing. In addition they analysis focused on historical observation (1980-2010) and did not assess future trends.

2.1 CO2 as a contributor to global greening

Page 4

MISLEADING

Had atmospheric CO2 levels continued declining, plant growth would have declined and eventually ceased. Below 180ppm, the growth rates of many C3 species are reduced 40-60% relative to 350ppm (Gerhart and Ward (2010)) and growth has stopped altogether under experimental conditions of 60-140ppm CO2. Some C4 plants are still able to grow at levels even as low as 10ppm, albeit very slowly (Gerhart and Ward (2010)).

Anonymous

The decline in atmospheric CO2 levels over the last few tens of millions of years stopped naturally, and for the last 800,000 years up until the Industrial Revolution did not show much of a trend, just fluctuating between about 170 and 280 parts per million. The hypothetical scenario of a further decline below these levels is not relevant – it is not the case that human-driven CO2 emissions have somehow saved us from declining CO2 levels and declining plant growth, as seems to be the implication behind this paragraph.

2.1 CO2 as a contributor to global greening

Page 5

MISLEADING

The overwhelming theme is that plants, especially C3 plants, benefit from extra CO2.

Anonymous

While individual plants benefit in isolation, the overall effect on an ecosystem and biodiversity can be detrimental due to some species benefitting more than others and out-competing them – for example, lianas responding more than trees, which they damage, encroachment of trees and shrubs into grasslands and savannahs, and the promotion of invasive species and weeds.

2.1 CO2 as a contributor to global greening

Page 5

MISLEADING

There are two mechanisms by which CO2 confers a growth benefit

Anonymous

A "growth benefit" to the plant is not necessarily beneficial in other ways – for example, from IPCC AR6: "Perennial crops and root crops may have a greater capacity for enhanced biomass under elevated CO2 concentrations, although this does not always result in higher yields. For some food crops, nutrient density declines due to elevated CO2." And: "Elevated CO2 reduces some important nutrients such as protein, iron, zinc and some grains, fruit or vegetables to varying degrees depending on crop species and cultivars."

2.1 CO2 as a contributor to global greening

Page 5

MISLEADING

The gains induced by increasing CO2 from 150ppm to 350ppm continue under a further doubling to 700ppm.

Anonymous

This very simplistic illustration from a small laboratory study ignores key effects such as nutrient availability, which in the real world can constrain the response to elevated CO2.

Quote given to Carbon Brief

Supporting evidence

[Link1](#)

2.2 The alkaline oceans

Pages 17-18

MISLEADING

Section 2.2.1

Dr John Kennedy, climate scientist

"The first subsection builds towards the conclusion in the summary that 'ocean life is complex and much of it evolved when the oceans were acidic relative to the present'. Leaving aside the vacuity of this argument for the moment – life itself evolved when there was little oxygen in the atmosphere, the biochemical innovations that flooded the atmosphere with oxygen were catastrophic for life then, but see how we would do without it now – their citations are spare and strange particularly within the context of later arguments about the value of models and the contention that this is some sort of meaningful 'critical review'. The first paper they cite regarding long-term change in ocean pH is Krissansen-

Totton et al. (2018), which uses a model to constrain climate and ocean pH of the early Earth up to the present. They find that ocean pH evolves monotonically from 6.6 (see the abstract of the paper for the broad

uncertainty ranges) at 4.0 Ga to 7.0 at the Archean-Proterozoic boundary, and to 7.9 at the Proterozoic-Phanerozoic boundary reaching a modern value of 8.2. While we might raise an eyebrow that the 'critical review' finds models are good enough for the herculean task of reproducing almost the whole of Earth's climate history, but not for understanding the past 200 years, the eyebrow is likely to go shooting off your face when you reach the sentence in the 'critical review' that says: 'Even if the water were to turn acidic, it is believed that life in the oceans evolved when the oceans were mildly acidic with pH 6.5 to 7.0.' I derive little comfort from the fact that simple life forms evolved in such conditions. The gist of the 'critical review' isn't that simple life forms will survive the current warming, but that human society supported by a flourishing biosphere will not just survive but thrive. Anyway, this is only part of an argument and the whole of the argument is never really spelled out. It seems to go something like this: pH of the ocean varied in the past and we exist today, therefore we will always exist and pH of the ocean is unimportant.

"The second, shorter, long-term perspective, which feeds into this argument, mixes up surface pH (as shown in Figure 2.3 from the CMEMS dataset) with deep ocean pH (from Rae et al. (2018)) who (according to their abstract) 'present deep-sea coral boron isotope data that track the pH – and thus the CO₂ chemistry – of the deep Southern Ocean over the past forty thousand years'. 'Deep' and 'track' are the operative words here. The estimated changes are 'deep', from a depth of around 750 metres and not the surface. Regarding 'track', the numbers quoted in the 'critical review' – pH of 7.4 to 7.5 20,000 years ago – came presumably from Figure S1 in the Rae paper, which provides an approximate conversion of the boron isotopes to pH. How very very approximate they are is shown by an inset uncertainty range, which extends from well below 7.4 to well above 7.6 suggesting great care is needed in the interpretation of the absolute pH values."

Quote from [external source](#)

2.2 The alkaline oceans

Pages 18-19

MISLEADING

Section 2.2.2

Dr John Kennedy, climate scientist

"The first two paragraphs of the 'critical review' are on that famous American landmark the Great Barrier Reef. And why not? Well. One 'why not' can be found in the IPCC report (AR6 WG2). Chapter 11 has a box ('Box 11.2 | The Great Barrier Reef in Crisis'). It doesn't mention ocean acidification as a risk to the GBR at all (though OA is mentioned frequently elsewhere). The two big risks mentioned are bleaching in response to marine heatwaves and erosion caused by tropical cyclones. Neither of these factors is unconnected to climate change. Ocean acidification may not be a risk to the GBR, but climate change certainly is. The AIMS website which is referenced in the 'critical review' even notes 'a high tolerance in massive Porites to ocean acidification'. The GBR is introduced here as a 2,300km long straw man.

"The rest of the section concerns itself with the more general impacts of ocean acidification. But only glancingly. They cite Browman (2016) on the lack of null results in the literature and offer, as an example, Clements et al. (2021) which is about the direct effects of OA on the behaviour of fish specifically (not the reefs themselves) though it does have a juicy metascientific quote that serves their purpose of suggesting that discussion of the topic is one-sided. If anything, Clements et al. shows that the literature is no longer one-sided so it rather weakens the point they are trying to make... The Browman article is also somewhat meta and

points out that papers on ocean acidification were appearing at an average rate of 300 per year between 2006 and 2015, with around 600 articles per year in each of 2013, 2014 and 2015. How many are there now? I don't know. The Browman and Clements articles are both old-as in the context of a fast-moving field. A simple Google Scholar search will show you that not only are there huge numbers of papers mentioning the topic in the past five years, but there are even lots of review papers and meta analyses on the topic which cover a much broader range of impacts. Summarising that literature with just 12 references (including links to the data used) is not adequate by any definition."

2.1 CO2 as a contributor to global greening

Page 6

MISLEADING

Deryng et al. (2016) surveyed evidence on crop water productivity (CWP), the yield per unit of water used, drawing attention to the potential for CO2 both to enhance photosynthesis and to reduce leaf-level transpiration (water loss during leaf respiration). They surveyed all available FACE data (Free Air CO2 Enrichment – see Chapter 9) on crop yield changes for maize (corn), wheat, rice, and soybean and combined it with crop model data simulating yield responses as of 2080 under the extreme RCP8.5 emissions scenario in four growing regions (tropics, arid, temperate and cold) each of which were split into rainfed and irrigated sub-regions. They reported that models without CO2 fertilisation predicted CWP losses in every region, but those were more than offset by CO2 fertilisation so that all regions showed a net CWP gain. Deryng et al. (2016) also reported that negative impacts of warming on wheat and soybean yields were fully offset by CWP gains and mitigated by up to 90% for rice and 60% for maize.

Dr Delphine Deryng, lead author, IPCC AR6 WG2

While those are general conclusions of the paper, they are misleading by not mentioning the considerable discrepancy among modelled results. In fact, this paper was the first of its kind to present findings from the first global modelling intercomparison initiative of global gridded crop models, focusing specifically on how state-of-the-art models represented CO2 effects on crop yield and evapotranspiration, highlighting these effects as a dominant source of uncertainty in the results, outpassing the uncertainty resulting from the use of different climate change projections. The supplementary information of the paper includes the detailed uncertainty analysis. A key message of the paper was also to highlight the needs for further research on the effects of CO2 on crops and their representation in crop models. Toreti et al. (2020) provides a comprehensive review of the uncertainties associated with the effects of elevated CO2 on crops,

2.1 CO2 as a contributor to global greening

Page 6

FALSE

Deryng et al. (2016) assumed that climate change would "exacerbate water scarcity". Yet while models do predict that drylands will expand under climate warming, current data show the opposite: greening is happening even in arid areas.

Dr Delphine Deryng, lead author, IPCC AR6 WG2

Greening and water scarcity are processes related to different carbon and water cycles, respectively. They cannot be directly compared. Deryng et al. (2016) didn't assume but reported findings from peer-reviewed scientific studies on water scarcity trends. Deryng et al (2016) specifically stated: "Research indicates unabated climate change will exacerbate water scarcity around the world. This is thought to threaten agricultural productivity and food security, especially in arid regions, where agriculture relies heavily on irrigation and consumes the majority of diverted freshwater."

2.1 CO2 as a contributor to global greening

Page 6

FALSE

The IPCC has only minimally discussed global greening and CO2 fertilisation of agricultural crops. The topic is briefly acknowledged in a few places in the body of the IPCC 6th and earlier assessment reports but is omitted in all summary documents. Section 2.3.4.3.3 of the AR6 WG1 report, entitled "global greening and browning," points out that the IPCC special report on climate change and land had concluded with high confidence that greening had increased globally over the past two-to-three decades. It then discusses that there are variations in the greening trend among data sets, concluding that while they have high confidence greening has occurred, they have low confidence in the magnitude of the trend. There are also brief mentions of CO2 fertilization effects and improvements in water use efficiency in a few other chapters in the AR6 WG1 and 2 reports.

Dr Delphine Deryng, lead author, IPCC AR6 WG2

Chapter 5 of IPCC WG2 AR6 has reported the state of knowledge of CO2 fertilisation effects on crops, including photosynthesis stimulation, evapotranspiration reductions, as well as elevated CO2 effects on the quality of crops. These are widely discussed throughout the chapter, including in figures 5.6, 5.7, and 5.11, as well as in sections 5.2.1 (Detection and Attribution of Observed Impacts), 5.4.1 (Observed Impacts of crop-based systems), 5.4.3 (Projected Impacts of crop-based systems), 5.4.4 (Adaptation Options of crop-based systems), 5.5.3 (Projected Impacts of Livestock-Based Systems), 5.6.2 (Projected Impacts of forestry systems), 5.10.3 (Projected Impacts of mixed systems), 5.12.2 (Mechanisms for Climate Change Impacts on Food Security), 5.12.4 (Projected Impacts on Food Security). The effects of elevated CO2 on food systems are also included in the summary tables 5.9 (Observed and predicted impacts of climate change on selected medicinal plant species) and 5.14 (Impacts from climate change drivers on the four dimensions of food security).

2.1 CO2 as a contributor to global greening

FALSE

Overall, however, the policymaker summaries, technical summaries and synthesis reports of AR5 and AR6 do not discuss the topic.

Dr Delphine Deryng, lead author, IPCC AR6 WG2

The technical summary does include a statement of CO₂ fertilisation effects on vegetation and crops. Specifically in the observed and projected impacts sections (TS.B.1.5 and TS.C.1.4) as well as in Figure TS.6 FOOD-WATER. The summary for policymakers includes a summary of the findings. In the case of agriculture the overall key risks are reported, which are based on the overall assessment of observed and projected impacts of climate change, including effects of CO₂ fertilisation, as well as potential contribution of adaptation measures on global and regional food production and food security.

2.1 CO₂ as a contributor to global greening

Page 6

MISLEADING

The IPCC has only minimally discussed global greening and CO₂ fertilisation of agricultural crops.

Anonymous

The IPCC has extensively discussed the promotion of plant growth by rising atmospheric CO₂ concentrations and consequent effects on global vegetation and land carbon sinks, including in summary documents – just not using the specific term "global greening" since other terms are used. The AR6 WG1 carbon cycle chapter prominently discusses the uptake of carbon in land ecosystems, e.g. in the executive summary page ("The ocean and land sinks of CO₂ have continued to grow over the past six decades in response to increasing anthropogenic CO₂ emissions (high confidence)") and in Frequently Asked Question 5.1. The WG1 summary for policymakers includes a figure showing the land carbon sink (Figure SPM.7). In WG2, chapter 2 on terrestrial ecosystems also discusses this, e.g. in the executive summary: "Biome shifts and structural changes within ecosystems have been detected at an increasing number of locations, consistent with climate change and increasing atmospheric CO₂ (high confidence)" and "A combination of changes in grazing, browsing, fire, climate and atmospheric CO₂ is leading to observed woody encroachment into grasslands and savannah."

The WG2 technical summary includes a figure showing woody encroachment (Figure TS12) and the WG2 summary for policymakers states that "at the global scale, terrestrial ecosystems currently remove more carbon from the atmosphere than they emit", but also notes: "However, recent climate change has shifted some systems in some regions from being net carbon sinks to net carbon sources." (page 20 footnote 39). The WG2 food chapter extensively discusses effects of elevated CO₂ on crops, including both past and projected future changes. The summary documents focus on overall outcomes from the combined effects of climate change, elevated CO₂ and other changes in atmospheric composition. The IPCC also specifically notes that elevated CO₂ can reduce nutritional quality in crops.

2.1 CO₂ as a contributor to global greening

Page 6

FALSE

The topic is briefly acknowledged in a few places in the body of the IPCC 6th and earlier assessment reports.

Anonymous

The topic of CO₂ fertilisation effects, including their limitations and interactions with other drivers of change, are extensively discussed in AR6 WG2 chapter 5 (Food, Fibre and Other Ecosystem Products). The term "CO₂" appears 136 times in that chapter. In the WG1 report, Chapter 5 is "Global Carbon and Other Biogeochemical Cycles and Feedbacks" and, again, extensively includes discussion of CO₂ effects as part of the carbon cycle.

2.1 CO₂ as a contributor to global greening

Page 6

FALSE

Overall, however, the policymaker summaries, technical summaries and synthesis reports of AR5 and AR6 do not discuss the topic.

Anonymous

The WG1 summary for policymakers includes a figure showing the land carbon sink (Figure SPM.7) and the caption includes: "Land and ocean carbon sinks respond to past, current and future emissions...During the historical period (1850-2019) the observed land and ocean sink took up 1430 GtCO₂ (59% of the emissions)." The WG2 technical summary includes a figure showing woody encroachment (Figure TS12) and the WG2 summary for policymakers states: "At the global scale, terrestrial ecosystems currently remove more carbon from the atmosphere than they emit." It also notes: "However, recent climate change has shifted some systems in some regions from being net carbon sinks to net carbon sources." In AR5, the WG1 SPM says: "Of these cumulative anthropogenic CO₂ emissions...160 [70 to 250] GtC have accumulated in natural terrestrial ecosystems (i.e., the cumulative residual land sink)."

2.2 The alkaline oceans

Page 7

MISLEADING

Even if the water were to turn acidic, it is believed that life in the oceans evolved when the oceans were mildly acidic with pH 6.5 to 7.0 (Krissansen-Totton et al. (2018)).

Dr Josh Krissansen-Totton, assistant professor, Earth and space sciences, University of Washington

"Krissansen-Totton told WIRED in an email that his work on ocean acidity billions of years ago has 'no relevance' to the impacts of human-driven ocean acidification today and that today calcium carbonate saturation is quickly diminishing in the ocean alongside rising acidity. Dissolved calcium carbonate is essential for many marine species, particularly those that rely on it to build their shells.' The much more gradual changes in ocean pH we observe on geologic timescales were typically not accompanied by the rapid changes in carbonate saturation that human CO₂ emissions are causing, and so the former are not useful analogs for assessing the impact of ocean acidification on the modern marine biosphere,' he says."

2.2 The alkaline oceans

Page 7

MISLEADING

Even if the water were to turn acidic, it is believed that life in the oceans evolved when the oceans were mildly acidic with pH 6.5 to 7.0 (Krissansen-Totton et al. (2018)).

Dr James Rae, reader, geochemistry and climate, University of St Andrews

Modern marine life and ecosystems (e.g. coral reefs and open ocean fisheries) are very different from the initial lifeforms that evolved in the earliest oceans (e.g. bacteria, single-celled organisms) and so have different adaptive ranges and vulnerabilities. In the same way that the environmental conditions which were suitable for dinosaurs have little relevance for optimal conditions for humans, there is little relevance in comparing early ocean bacterial habitats to the conditions to which modern marine life has adapted.

2.2 The alkaline oceans

Page 7

MISLEADING

On the time scale of thousands of years, boron isotope proxy measurements show that ocean pH was around 7.4 or 7.5 during the last glaciation (up to about 20,000 years ago) increasing to present-day values as the world warmed during deglaciation (Rae et al. (2018)).

Dr James Rae, reader, geochemistry and climate, University of St Andrews

The use of "ocean pH" in this statement is misleading, as it seems to imply whole ocean pH or (following from the text above) the pH of the surface ocean, whereas the boron isotope study referenced here (of which I was the first author) apply only to the deep Southern Ocean. These are completely different habitats occupied by completely different species. The habitats of most concern with respect to ocean acidification are in the surface (e.g. coral reefs, key fisheries), where pH was higher than today during the last ice age (e.g. Shao et al., 2019), not lower as suggested in figure 5 of Shao et al. (2019).

Quote given to Carbon Brief

2.2 The alkaline oceans

Page 7

MISLEADING

Thus, ocean biota appear to be resilient to natural long-term changes in ocean pH since marine organisms were exposed to wide ranges in pH.

Dr James Rae, reader, geochemistry and climate, University of St Andrews

Natural long-term changes in ocean pH have a fundamentally different impact on ocean chemistry than rapid input of carbon from fossil fuels (see Honisch et al. (2011)). When ocean pH is lowered rapidly (e.g. on decadal to centennial timescales), the abundance of carbonate ions decreases rapidly. As these carbonate ions are the most critical ingredient for marine shell formation, shells become harder to grow. Technically, this is known as a drop in calcium carbonate saturation state and it makes calcium carbonate shell formation more energetically costly (e.g. Gagnon et al., (2021)). In contrast, when ocean pH is lowered slowly (e.g. on timescales of a thousand years or more), the dissolution of seafloor calcium carbonate, alongside weathering of rocks on land, has a buffering effect on ocean saturation state, allowing shell formation to continue unimpeded despite the lower pH. Today, anthropogenic CO₂ emission is lowering ocean pH on decadal to centennial timescales, which are too rapid for these buffering processes to keep up with, resulting in lower calcium carbonate saturation states, and making shell formation more energetically costly and enhancing environmental stress on these organisms.

2.2 The alkaline oceans

Page 8

MISLEADING

Similarly, a meta-analysis (Clements et al. (2021)) of the negative effects of ocean acidification on reef fish behavior found what they called a “decline effect”: initially dramatic conclusions published in prominent journals showing apparently large impacts of acidification tended to be followed up by subsequent studies on larger sample sizes yielding much smaller and typically non-existent effects. They call for their colleagues to improve research practices to counter the “decline effect”: [The] vast majority of studies with large effect sizes in this field tend to be characterised by low sample sizes, yet are published in high-impact journals and have a disproportionate influence on the field in terms of citations. We contend that ocean acidification has a negligible direct impact on fish behaviour, and we advocate for improved approaches to minimise the potential for a decline effect in future avenues of research (Clements et al. (2021)).

Dr Jeff Clements, marine ecologist, Fisheries and Oceans Canada (Gulf Region)

“Clements... says that the way the DoE report cites his research on ocean acidification and fish behavior is accurate ‘from an explicit textual perspective’... Clements says in an email to WIRED that just because his review of the literature found fish behavior to be relatively unaffected by ocean acidification does not mean that a myriad of other ocean ecosystems, biological processes and species will fare similarly. Other work from his lab, meanwhile, has underscored the vulnerability of mussels to ocean warming and looked at how heat waves negatively alter clam behavior...’ I want to make it clear that our results should not be interpreted to mean ocean acidification (or climate change more generally) is not a problem,’ he tells WIRED. ‘While effects on fish behavior may not be as severe as initially thought, other species and biological processes are certainly vulnerable to the impacts of acidification and the compendium of other climate change stressors that our oceans are experiencing.’”

2.2 The alkaline oceans

Page 8

MISLEADING

Similarly, a meta-analysis (Clements et al. (2021)) of the negative effects of ocean acidification on reef fish behaviour found what they called a “decline effect”: initially dramatic conclusions published in prominent journals showing apparently large impacts of acidification tended to be followed up by subsequent studies on larger sample sizes yielding much smaller and typically non-existent effects.

Prof Fredrik Jutfelt, professor of fish ecophysiology, Norwegian University of Science and Technology

The way the DoE report cites our own work is flawed, as they use a specific finding in a small subsection of the field to represent the state of the entire field. This is intellectually dishonest and unscientific, and suggests either gross incompetence or an underlying bias.

Quote given to Carbon Brief

2.2 The alkaline oceans

Page 8

MISLEADING

In summary, ocean life is complex and much of it evolved when the oceans were acidic relative to the present. The ancestors of modern coral first appeared about 245m years ago. CO2 levels for more than 200m years afterward were many times higher than they are today. Much of the public discussion of the effects of ocean “acidification” on marine biota has been one-sided and exaggerated.

Dr John Kennedy, climate scientist

The factoid about coral appearing 245m years ago is unreferenced and not previously mentioned in the section. The contention regarding ‘much of the public discussion’ is likewise unreferenced and not mentioned elsewhere in the section. Public discussion and scientific discussion are two different things.

Public discussion isn’t discussed at all and, anyway, the ‘critical review’ is supposedly reviewing the science. I think it’s safe to say it has failed there too. Quote from external source

2.2 The alkaline oceans

Page 8

MISLEADING

In summary, ocean life is complex and much of it evolved when the oceans were acidic relative to the present. The ancestors of modern coral first appeared about 245m years ago. CO2 levels for more than 200m years afterward were many times higher than they are today. Much of the public discussion of the effects of ocean “acidification” on marine biota has been one- sided and exaggerated.

Dr James Rae, reader, geochemistry and climate, University of St Andrews

As discussed above, long-term geological pH changes are not a good analogue for a rapid drop in pH of the type happening today, for the key reason that a rapid pH drop results in lowered calcium carbonate saturation state, which makes shell formation harder (e.g. Honisch et al., (2011)). To find better analogues for modern pH decline in the geological record, we need to look at times when ocean pH dropped more quickly. Data of this type are compiled in a recent study by Trudgill et al. (2025). These show that all of the major mass extinction events in the ocean for which we have pH reconstructions are associated with a rapid drop in ocean pH. The geological record thus suggests that rapid pH decline is a matter for serious concern for marine ecosystems and the communities and economies which they support.

Quote given to Carbon Brief

Supporting evidence

[Link1](#)
[Link2](#)

References

Page 9

FALSE

Chen, X., Wang, Y., Liu, Y., and Piao, S. (2024). The global greening continues despite increased drought stress since 2000. Global Ecology and Conservation, 49, e02791.

Anonymous

The author list is incorrect on this citation. It should be Xin Chen, Tiexi Chen, Bin He, Shuci Liu, Shengjie Zhou and Tingting Shi. It falsely associates the paper with well-known authors and demonstrates lack of attention to detail.

3 Human influences on the climate

Page 11

MISLEADING

The IPCC has downplayed the role of the sun in climate change, but there are plausible solar irradiance reconstructions that imply it contributed to recent warming.

Dr Theodosios Chatzistergos, astrophysicist, Max Planck Institute for Solar System Research

This is a vague and potentially misleading statement. The IPCC AR6 adopted the solar radiative forcing values recommended by CMIP6, while AR5 used those from CMIP5. In both cases, the TSI [total solar irradiance] reconstructions selected were the most advanced and extensively scrutinised available at the time (Matthes et al. (2017)). The notion that there exist "plausible" solar irradiance reconstructions implying a solar contribution to recent warming is misleading, since it leaves it vague as to how much it contributed. The most scientifically robust irradiance reconstructions indicate that this contribution has been relatively small in recent decades. The wording of this statement appears to implicitly reference the work of Connolly et al. (2021) and (2023), although only the former is cited in the DoE report. Connolly et al. (2021) argued that a significant portion, or even most, of recent global warming could be attributed to solar variability. However, their approach involved cherry-picking and balancing 16 TSI reconstructions: eight with low long-term variability and eight with high variability. To create this balance, they included outdated or superseded models while omitting many low-variability reconstructions.

The high-variability series used by Connolly et al. (2021):

- Hoyt and Schatten (1993) has been thoroughly discredited (see Chatzistergos (2024)). It includes arbitrary manual adjustments and even fabricated data, with some values seemingly copied from another solar index.
- Lean et al. (1995) is an early version of the NRL [Naval Research Laboratory] model that has since been superseded by multiple updated versions, most recently NRLTSI2/NNL (Coddington et al. (2016) and (2019)).
- Bard et al. (2000) used a simplified linear conversion from cosmogenic isotope production (e.g., ^{10}Be) to TSI, without accounting for nonlinear effects such as geomagnetic modulation, atmospheric transport processes, or climate-driven deposition variations. These omissions have been addressed in more physically realistic models like SATIRE-M [Spectral And Total Irradiance REconstructions] (Wu et al. (2018)), which show significantly lower long-term variability. Furthermore, Delaygue and Bard (2011) revised the original Bard et al. (2000) reconstruction which was exhibiting low long-term variability, yet this update was ignored by Connolly et al. (2021).
- Shapiro et al. (2011), an older high-variability model, was effectively replaced by Egorova et al. (2018), which itself has been criticised by Yeo et al. (2020) for exaggerating long-term TSI changes. - Egorova et al. (2018) was included four times in the Connolly et al. (2021) analysis. Including Shapiro et al. (2011), a predecessor of Egorova's model, the same model family was effectively used five times, artificially inflating the weight of high-variability reconstructions.

Crucially, in all these high-variability models, the long-term TSI trends were not derived from observational constraints but were imposed as assumptions. Modern revisions of the NRL model (Lean (2018) and Coddington et al. (2019)) and the Hoyt and Schatten model (Chatzistergos (2024)) have significantly reduced these assumed trends to align with observational evidence. Therefore, treating these outdated, superseded, or methodologically flawed reconstructions as equally probable alternatives to modern, validated TSI models is scientifically unjustified. It creates a false equivalence that misrepresents the current state of solar irradiance research. Connolly et al. (2023), although not cited in the DoE report, extended the analysis to 27 TSI series. However, the same methodological issues persist. Many of the added reconstructions are either outdated or redundant versions of older models.

Notably, the highest solar attribution results again stem from Hoyt and Schatten (1993) and Bard et al. (2000), both of which have been superseded and shown to be unreliable. Finally, the attribution method used by Connolly et al. (2021) was directly critiqued by Richardson and Benestad (2022), who identified substantial flaws in their regression methodology and treatment of uncertainty. Even with the analysis presented in Connolly et al. (2021) and (2023) when the outdated, superseded and implausible TSI series are removed, the

result is that the solar contribution to global warming is significantly smaller than the anthropogenic one.

3.1 Components of radiative forcing and their history

Page 12

MISLEADING

The IPCC assesses the change in the radiative forcing by the sun to be negligible, based on their preference for data reconstructions that imply minimal solar change since pre-industrial times.

Dr Theodosios Chatzistergos, astrophysicist, Max Planck Institute for Solar System Research

The selection of TSI reconstructions for use in CMIP6 and IPCC AR6 was based on the scientific robustness and performance of the models, rather than the magnitude of TSI variability they imply (Matthes et al. (2017)). The two reconstructions adopted were SATIRE and NRLTSI (now referred to as>NNLTSI). These models were chosen because they represent the most advanced TSI reconstructions currently available. SATIRE is a semi-empirical, physics-based model, while>NNLTSI is a proxy-based regression model. Both have been extensively validated and demonstrate excellent agreement with direct satellite measurements of TSI, making them the most reliable choices for climate modeling to date.

3.1 Components of radiative forcing and their history

Page 12

MISLEADING

But Connolly et al. (2021) reviewed 16 different Total Solar Irradiance (TSI) reconstructions in the literature covering the years 1600-2000; the reconstructions vary from almost no change in TSI to a relatively large upward trend. Those authors note that the variation in TSI reconstructions combined with variations in surface temperature reconstructions allows for inferences consistent with either no or most 20th century warming being attributable to the sun.

Dr Theodosios Chatzistergos, astrophysicist, Max Planck Institute for Solar System Research

The approach by Connolly et al. (2021) involved cherry-picking and balancing 16 TSI reconstructions: eight with low long-term variability and eight with high variability. To create this balance, they included outdated or superseded models while omitting many low-variability reconstructions.

The high-variability series used by Connolly et al. (2021):

- Hoyt and Schatten (1993) has been thoroughly discredited (see Chatzistergos (2024)). It includes arbitrary manual adjustments and even fabricated data, with some values seemingly copied from another solar index.
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(2019)).

– Bard et al. (2000) used a simplified linear conversion from cosmogenic isotope production (e.g., ^{10}Be) to TSI, without accounting for nonlinear effects such as geomagnetic modulation, atmospheric transport processes, or climate-driven deposition variations. These omissions have been addressed in more physically realistic models like SATIRE-M [Spectral And Total Irradiance REconstructions] (Wu et al. (2018)), which show significantly lower long-term variability.

Furthermore, Delaygue and Bard (2011) revised the original Bard et al. (2000) reconstruction which was exhibiting low long-term variability, yet this update was ignored by Connolly et al. (2021).

– Shapiro et al. (2011), an older high-variability model, was effectively replaced by Egorova et al. (2018), which itself has been criticised by Yeo et al. (2020) for exaggerating long-term TSI changes. – Egorova et al. (2018) was included four times in the Connolly et al. (2021) analysis. Including Shapiro et al. (2011), a predecessor of Egorova's model, the same model family was effectively used five times, artificially inflating the weight of high-variability reconstructions.

Crucially, in all these high-variability models, the long-term TSI trends were not derived from observational constraints but were imposed as assumptions. Modern revisions of the NRL model (Lean (2018) and Coddington et al. (2019)) and the Hoyt and Schatten model (Chatzistergos (2024)) have significantly reduced these assumed trends to align with observational evidence. Therefore, treating these outdated, superseded, or methodologically flawed reconstructions as equally probable alternatives to modern, validated TSI models is scientifically unjustified. It creates a false equivalence that misrepresents the current state of solar irradiance research.

3.1 Components of radiative forcing and their history

Page 13

MISLEADING

A particularly thorny issue is the gap in TSI data between 1989 and 1991 due to a delay in the launch of a monitor following the Space Shuttle Challenger

” [A gap in TSI measurements between the ACRIM-1 and ACRIM-2 satellite monitoring experiments] as a "particularly thorny" issue. While it does contribute to uncertainty in the long-term trend of direct TSI measurements, a growing body of evidence challenges the notion of a TSI increase during the ACRIM-gap, evidence which the DoE report entirely overlooks. Notable examples include Amdur & Huybers (2023), Chatzistergos et al. (2025) and Krivova et al. (2009).

Quote given to Carbon Brief

3.1 Components of radiative forcing and their history

Page 13

FALSE

Connolly et al. (2021) found that the IPCC's consensus statements on solar forcing were formulated prematurely through the suppression of dissenting scientific opinions.

Dr Theodosios Chatzistergos, astrophysicist, Max Planck Institute for Solar System Research

This is yet another statement in the DoE report that is vague. It is not clear what they refer to with consensus, is this about the long-term reconstructions, is it just about the ACRIM-gap that this paragraph discusses? In any case, it appears as a general statement which as such has to be labelled as false. The claim that dissenting scientific opinions are being suppressed is unfounded.

Scientific consensus evolves through rigorous evaluation, not censorship. When significant methodological issues are identified, such as the arbitrary adjustments and fabricated data in the Hoyt and Schatten (1993) TSI reconstruction (Chatzistergos (2024)), it is scientifically appropriate to disregard such models as implausible. This is not suppression of dissenting voices, but the enforcement of standards for methodological soundness.

Another example is the Bard et al. (2000) TSI reconstruction, which has since been superseded by more advanced models. Bard et al. (2000) relied on a simplistic linear scaling of cosmogenic isotope production to estimate TSI variability, without accounting for the non-linear influence of geomagnetic field modulation on isotope production. This omission leads to inaccurate estimates of solar variability. Later reconstructions, such as those based on the SATIRE-M framework (e.g., Wu et al. (2018)), incorporate these critical non-linearities and have been shown to produce more consistent results with observational constraints. Albeit, uncertainties remain and more work is being invested in improving these reconstructions too. Furthermore, we have advanced physics-based irradiance reconstruction models, e.g. SATIRE-3D (Yeo et al. (2017) and (2020)), which have been used to set robust constraints on the magnitude of plausible TSI variations. As a result, irradiance reconstructions that exceed this constraint are considered less plausible than those that remain within it. Disregarding outdated or methodologically flawed reconstructions is a hallmark of scientific integrity, not suppression. The continued use of discredited models undermines robust scientific discourse and misrepresents the state of knowledge. A reminder here that the study by Connolly et al. (2021) cherry-picked 16 TSI reconstructions, deliberately balancing the sample by including eight with small long-term trends and eight with pronounced trends. The high-variation models they used are Hoyt and Schatten (1993), Lean (1995), Bard et al. (2000), Shapiro et al. (2011) and Egorova et al. (2018; used 4 different versions). Besides the issues with Hoyt and Schatten (1993) and Bard et al. (2000) discussed above, Lean (1995) is an outdated precursor to the NRL (now NNL) model and is no longer considered plausible. Shapiro et al. (2011) and Egorova et al. (2018) are different versions of the same model both exceeding the Yeo et al. 2020 constraint.

3.1 Components of radiative forcing and their history

Pages 22-24

MISLEADING

Section 3.1.1

Dr Mark Schoeberl, chief scientist, Science and Technology Corp

The paper by Jenkins et al. (2023) did not include volcanic aerosol effects and thus estimated the wrong sign of the Hunga volcano radiative forcing.

Subsequent papers (including my own) agree that Hunga would produce slight cooling. The inclusion of the Jenkins paper here suggests more uncertainty in the calculation than exists. All models and data analyses agree that Jenkins was incorrect (e.g. Stenchikov et al. (2025) and Zhuo et al. (2025)).

3.2 Future emission scenarios and the carbon cycle

Page 15

FALSE

Comparisons of past scenario groups against observations show that IPCC emission projections have tended to overstate actual subsequent emissions. For the IPCC third and fourth Assessment Reports a set of emission projections from the special report on emission scenarios was used; these were referred to as the SRES scenarios. McKittrick et al. (2012) showed that, when converted to per capita values, the SRES scenario emissions distribution was skewed upwards compared with observed trends.

Dr Zeke Hausfather, research scientist, Berkeley Earth

While some past IPCC emissions scenarios have overstated future total CO₂ emissions (IS92B, A1F1, RCP8.5), others have understated them (IS92D, B2, RCP6). In general total CO₂ emissions were on the high end of the range of both the 1992 IS92 scenarios and the 2000 SRES scenarios through 2015, before falling closer to the middle of the range in recent years. Notably both IS92 and SRES scenarios were all variations of baseline scenarios that did not explicitly include aggressive emissions mitigation.

3.2 Future emission scenarios and the carbon cycle

Page 15

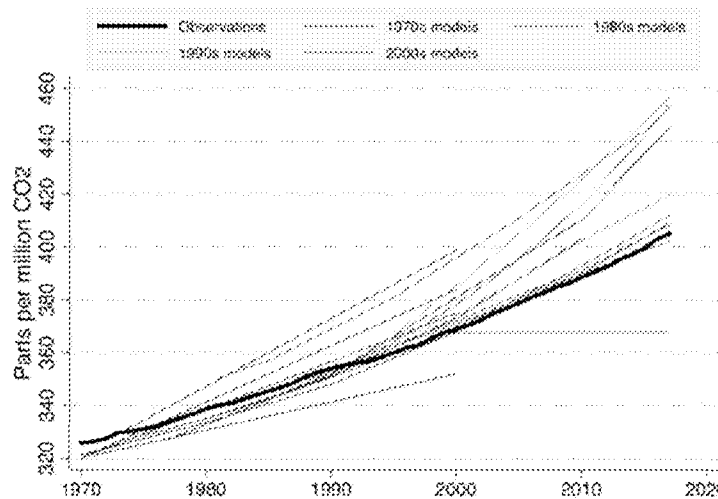
FALSE

Figure 3.2.1 Since the 1970s successive families of emission and concentration projections (colored lines) have consistently overestimated observations (black line). Source: Hausfather et al. (2019) Figure S4.

Dr Zeke Hausfather, research scientist, Berkeley Earth

Figure 3.2.1 focuses primarily on older climate models that predate the SRES scenarios. The only SRES scenarios included in the figure are A2 and A1B, and those actually track CO₂ concentrations quite well. The disagreement is primarily with 1970s and 1980s era models; however, as Figure 1 in Hausfather et al. (2019) notes the trend in total forcing in these early models is actually a tad low due to their exclusion of non-CO₂ GHGs.

Quote given to Carbon Brief

Supporting evidence

[Link1](#)

3.2 Future emission scenarios and the carbon cycle

Page 15

MISLEADING

The implausibility of the RCP8.5 scenario was examined by Burgess et al. (2021). The implausibility of RCP8.5 should not be interpreted as very unlikely (e.g. 95th 23 percentile) or a “worst case”, but rather as genuinely implausible owing to the implausibility of the inputs required to reach a forcing of 8.5 W/m². They noted that RCP8.5 has already diverged from observed trends in energy use and the near future trends diverge sharply from those of the International Energy Agency (IEA), which provides market-based projections of energy use for the coming decades. Pielke Jr. et al. (2022) further showed that the historic and projected IEA trends run near the bottom of the envelopes of both RCP projections and the more recent Shared Socioeconomic Pathway (SSP) scenario trends.

Dr Zeke Hausfather, research scientist, Berkeley Earth

The authors do not clearly differentiate between the implausibility of a particular emissions scenario like that used to generate RCP8.5 and the forcing outcome of 8.5 watts per meter squared. The latter can come about not just through emissions, but also carbon cycle feedbacks (Hausfather and Betts (2020)). While it remains quite unlikely in my view that we end up at 8.5W/m² by 2100 even with large carbon cycle feedbacks, it is not impossible under a RCP6.0 emissions pathway. Similarly, 8.5W/m² radiative forcing becomes increasingly plausible post-2100 if emissions continue.

3.2 Future emission scenarios and the carbon cycle

Page 16

FALSE

The authors mistakenly conflate total global observed CO₂ emissions in this text with CO₂ emissions from fossil fuels alone (which are shown in Figure 3.2.2). If total CO₂ emissions are used (including land-use emissions), then CO₂ emissions fall right in the middle of the SSPs; in-line with SSP2-4.5 and SSP4- 6.0, below SSP3-7.0 and SSP5-8.5, but above SSP1-1.9, SSP1-2.6 and SSP4-3.4.

3.2 Future emission scenarios and the carbon cycle

Page 17

MISLEADING

There are about 850Gt of carbon (GtC) in the Earth's atmosphere, almost all of it in the form of CO₂. Each year, biological processes (plant growth and decay) and physical processes (ocean

absorption and outgassing) exchange about 200GtC of that carbon with the Earth's surface (roughly 80GtC with the land and 120GtC with the oceans). Before human activities became significant, removals from the atmosphere were roughly in balance with additions. But burning fossil fuels (coal, oil, and gas) removes carbon from the ground and adds it to the annual exchange with the atmosphere.

Dr David Crisp, retired atmospheric physicist

The total mass of carbon in the atmosphere is increasing over time as the carbon dioxide concentration increases. Crisp et al. (2022) quoted a mass of 877 Peta grams of Carbon (Pg C; one Pg C is equivalent to one billion tonnes of carbon (GtC) or 3.67 billion tonnes of CO₂), which was a good estimate in 2020, when the atmospheric CO₂ dry air mole fraction (a measurement of concentration) was around 412ppm. Here, their estimate of “about 850GtC”, was relevant around a decade ago, when the average CO₂ concentration was closer to 400ppm. The quoted gross annual exchange of carbon between land and the atmosphere and between the ocean and the atmosphere are erroneous and their relative values are reversed. Here, they state that land exchanges 80GtC with the atmosphere and the oceans exchange 120GtC with the atmosphere. They do not cite specific sources for these numbers. They do not come from Crisp et al. (2022). That paper cites gross ocean-atmosphere carbon flux of 90GtC per year and gross land-atmosphere carbon fluxes between 120 and 175GtC per year.

They end this paragraph by noting that the 10.3GtC emitted by fossil fuel use and cement manufacturing is only about 5% of annual emissions by the land biosphere and oceans. This is a half-truth that is clearly intended to be misleading. It fails to recognise that the atmosphere and climate respond to the net emissions and removals of carbon, not the gross fluxes. The land biosphere and ocean both add and remove carbon from the atmosphere, while fossil fuel use and other human activities only add carbon to the atmosphere. When averaged over the globe and over the year, the land biosphere and ocean remove as much carbon as they emit, along with over half of these anthropogenic emissions, yielding net emissions that are negative and only about half as large as the positive anthropogenic emissions. In this context, the net anthropogenic emissions are more than twice as large as the net natural CO₂ fluxes.

3.2 Future emission scenarios and the carbon cycle

Page 18

MISLEADING

The carbon cycle accommodates about 50% of humanity's small annual injection of carbon into the air by naturally sequestering it through plant growth and oceanic uptake, while the remainder accumulates in the atmosphere (Ciais et al. (2013)). For that reason, the annual increase in atmospheric CO₂ concentration averages only about half of that naively expected from human emissions.

Dr David Crisp, retired atmospheric physicist

Here, the report authors recognise that existing observations show that natural processes in the land biosphere and ocean consistently remove about 50% of the anthropogenic CO₂ emissions. They also note that this ratio has been preserved as the fossil fuel emissions have increased. They attribute the increasing land uptake to the “global greening” phenomena described in chapter 2.1 of this work. However, that chapter fails to

recognise that the increasing leaf area index (LAI) does not always indicate increased CO₂ uptake. In particular, as noted in Crisp et al. (2022), many regions of the tropics, where the largest increases in LAI have been seen over the past 50 years, have started to transition from net CO₂ sinks to net sources of CO₂. These changes are due to the impacts of human activities (e.g. deforestation, forest degradation) and climate change (increasing temperature, drought, vapor pressure deficit).

The authors also fail to note that while tropical land is absorbing less CO₂, these losses are being compensated mostly by increased carbon uptake by forests at mid and high latitudes. There, climate change is driving longer, warmer growing seasons and permafrost thaw is allowing trees to grow deeper, more massive root systems that sequester more carbon in the soil. The rapid growth, combined with higher temperatures and more frequent droughts at these latitudes, result in larger and more frequent wildfires, which release CO₂.

In summary, while the fraction of the anthropogenic CO₂ that has been absorbed by the land biosphere has remained almost constant in response to increasing atmospheric CO₂ abundances, different parts of the world are responding differently to climate change. The focus on “global greening” is a massive oversimplification of the system.

3.2 Future emission scenarios and the carbon cycle

Pages 28-31

MISLEADING

Section 3.2.2: subsections on "CO₂ uptake by land processes" and "CO₂ uptake by ocean processes"

Dr David Crisp, retired atmospheric physicist

The last two subsections of this section focus on the carbon cycle models used by the Global Carbon Project. For both land and ocean, they note that this set of models predicts a range of estimates for the decadal uptake of CO₂ by the land and ocean carbon sinks. They use these results to foster doubt in the utility of these methods for predicting future change in the carbon cycle as it responds to climate change. This is interesting because they fail to note that all of the Dynamic Global Vegetation Models (DGVMs) included in this set include CO₂ fertilisation – a mechanism that the authors of this document advocate as a key benefit of increasing atmospheric CO₂ amounts.

3.3 Urbanisation influence on temperature trends

Page 20

MISLEADING

Peterson et al. had failed to find any difference in trends between rural and urban samples, although their definition of rural included local populations up to 10,000 persons while the relative influence of urbanisation begins well below that (Spencer et al. (2025)).

Dr Zeke Hausfather, research scientist, Berkeley Earth

While Peterson et al. (1999) used a single proxy for urbanity, the follow-up Hausfather et al. (2013) study used four different proxies for urbanity in the conterminous US. It found little residual urban heat island (UHI) bias in the homogenised NOAA data, even when only rural stations are used for breakpoint detection and correction in the homogenisation process to avoid any risk of aliasing in a UHI signal.

3.3 Urbanisation influence on temperature trends

Page 21

MISLEADING

The influence of UHI warming is logarithmic in population, in other words it is strongest at low population density then levels off as local urbanisation expands (Oke (1973) and Spencer et al. (2025)). Hence failure to find a difference in warming rates between urban and rural stations does not prove the absence of UHI contamination.

Dr Zeke Hausfather, research scientist, Berkeley Earth

This is both overly simplified – the actual environment immediately around the station matters a lot more than regional population density – and not particularly reflective of the literature. Some studies using pretty strict cutoffs for urbanity (e.g. Hausfather et al. (2013)) still find minimal differences in urban and rural stations.

3.3 Urbanisation influence on temperature trends

Page 21

FALSE

In summary, while there is clearly warming in the land record, there is also evidence that it is biased upward by patterns of urbanisation and that these biases have not been completely removed by the data processing algorithms used to produce climate data sets.

Dr Zeke Hausfather, research scientist, Berkeley Earth

The authors of the DoE report make a strong claim based on papers by some of their team (McKittrick and Spencer) while ignoring other studies that point otherwise. There is by no means agreement that there is a meaningful unremoved UHI bias in land temperatures in the surface record. Indeed, Spencer et al. (2025) only examines raw temperature records and gets a result comparable to that found by Hausfather et al. (2013), but does not do the follow up analysis of homogenised temperature records to see if the UHI bias has been effectively detected and removed (as Hausfather et al. (2013) find that it was).

The analysis in this section also ignores independent assessments by AIRS satellites (global; Susskind et al. (2019)) and the US Climate Reference Network (US; Hausfather et al. (2016)) that show the same rate of warming as the full land station network during the period of overlap, suggesting minimal UHI biases in recent decades. Finally, this section on UHI never bothers to point out that the world is mostly oceans, so even a significant (>10%) bias in land temperatures, if it existed, would have a much smaller effect on resulting global surface temperatures.

Part II: Climate response to CO2 emissions**4.2 Model-based estimates of climate sensitivity**

Page 27

FALSE

AR6 (2021) did not rely on climate model simulations in their assessment of climate sensitivity, relying instead on data-driven methods.

Anonymous

AR6 used multiple lines of evidence in the assessment of climate sensitivity: Understanding of climate processes, the instrumental record, palaeoclimates and model-based emergent constraints. Indeed, the authors of the DoE report contradict their own claim four paragraphs later by saying: "For AR6, the IPCC placed primary weight on the results of Sherwood et al. (2020) that combined historical data and palaeoclimate proxies with the process-based approach." Sherwood et al (2020) used climate models as one of their lines of evidence.

4.3 Data-driven estimates of climate sensitivity

Page 28

MISLEADING

Most climate models simulate that rising GHGs will weaken the west-east temperature gradient, which led the IPCC in AR6 to conclude that data-driven ECS estimates understated the future ECS value. However, Seager et al. (2019) pointed out that, contrary to models, the west-east temperature gradient has been strengthening over time. They further argued that the mechanism predicting otherwise in climate models was based on a faulty characterisation of oceanic dynamics and there is no reason to expect the gradient to weaken. A similar argument was recently made by Lee et al. (2024), who concluded that "the trajectory of the observed trend reflects the response to increasing GHG loading in the atmosphere"; in other words, GHG warming should lead to a future strengthening rather than a weakening of the temperature gradient. Increased efficiency of atmospheric cooling implies, if anything, that the future ECS in a warming climate might be lower than current estimates.

Dr Richard Seager, Ewing Lamont research professor, Columbia University

The report is right to point out that we have drawn attention to the fact that the observed gradient has been strengthening while models robustly predict a weakening in response to rising GHGs. The report is also right that we suggested models get the response wrong due to biases in how they simulate the tropical Pacific Ocean... But inferences on the relation between SST, radiation and climate sensitivity for the short time period (strongly influenced by natural internal variability) are not readily transferable to understand these relations for the forced response in the gradient. I don't think we know what

the implications for climate sensitivity are of the problem models have in reproducing the observed pattern of tropical Pacific SST change.

4.3 Data-driven estimates of climate sensitivity

Page 28

MISLEADING

An argument emphasised in AR6 is that data-driven ECS estimates might understate the future warming response to GHGs because of a so-called “pattern effect” (Forster et al. (2021)). The tropical Pacific is believed to strongly influence the overall efficiency with which the Earth radiates heat to space, but some regions remove heat more efficiently than others. If the west- to-east temperature gradient in the tropical Pacific is weakened in a warming climate, warming would concentrate where heat is less efficiently removed, raising ECS.

Prof Piers Forster, professor of climate physics, University of Leeds

The citation is ok, but rather offhand and dismissive, given the large amount of evidence assessed on the pattern effect in the IPCC report – it’s my chapter 7 which is cited. I also find that the literature on the pattern effect which the section... goes on to discuss is skewed and biased towards suggesting a small GHG cooling. It is especially missing a lot of other literature with conflicting evidence. Lots of literature that we cite in the IPCC report and evidence published since – including my own work – suggests a real pattern effect and high climate sensitivity. If you are going to present conflicting arguments to my IPCC chapter produced by many international authors and three rounds of peer review, including multiple government reviews, I think you would need to explain where these other studies we referenced in IPCC go wrong. I therefore find their argument weak.

4.3 Data-driven estimates of climate sensitivity

Page 28

MISLEADING

A similar argument was recently made by Lee et al. (2024), who concluded that “the trajectory of the observed trend reflects the response to increasing GHG loading in the atmosphere”; in other words, GHG warming should lead to a future strengthening rather than a weakening of the temperature gradient.

Increased efficiency of atmospheric cooling implies, if anything, that the future ECS in a warming climate might be lower than current estimates.

Prof Sukyoung Lee, distinguished professor of meteorology

The report cited my article out of context. Current climate models predict tropical Pacific sea surface temperature (SST) gradients that do not align with observational trends, whereas the simple model used in my study does. This does not mean that the climate models have no value for predicting the effects

of human activities on future climates. My study simply identified one specific aspect where models may need to be improved to make the predictions more accurate.

Quote given to Carbon Brief

Supporting evidence

[Link1](#)

5.5 Stratospheric cooling

Page 38

MISLEADING

An important element of the expected general “fingerprint” of anthropogenic climate change is simultaneous warming of the troposphere and cooling of the stratosphere. The latter feature is also influenced by ozone depletion and recovery. AR6 acknowledged that cooling had been observed but only until the year 2000. The stratosphere has shown some warming since, contrary to model projections.

Dr John Kennedy, climate scientist

“The poverty of their viewpoint is exemplified in the section on ‘stratospheric cooling’ about one-third of which consists of a long quote from the IPCC AR6 WG1 chapter 2, enough to cite a description of how stratospheric temperatures have changed, but completely ignoring the section on the causes which can be found in section 3.3.1.2.2 of the IPCC WG1 report... They can’t even be bothered to finish the one additional quote that takes up much of the rest of the section, the one from Philipona et al. (2018). The quote, which is from the abstract is cut short with a full stop, where the abstract goes on, after a comma, to say: ‘which is consistent with a reversal from ozone depletion to recovery from the effects of ozone-depleting substances.’ In other words, it’s not that simple and the report relies for its effect on you not digging any further, not even the tiniest little bit.”

5.5 Stratospheric cooling

Page 39

MISLEADING

A combination of tropospheric warming and stratospheric cooling is a commonly cited “fingerprint” of anthropogenic climate change. Stratospheric warming since 2000 coincides with continued surface and tropospheric warming, a pattern that is not found in climate model simulations and is not apparently consistent with the anthropogenic fingerprint.

Dr Benjamin Santer, atmospheric scientist, Lawrence Livermore National Laboratory

The DoE claim is not true. Climate models can and do show recovery of lower stratospheric temperature after 2000 in response to ozone recovery (and in accord with satellite observations). Over the full satellite era (1986 to 2024), models show very large cooling of the mid- to upper stratosphere in response to human-caused

changes in CO2 and ozone (see Fig. 1 in the appended paper).

The observed vertical structure of atmospheric temperature change IS consistent with model predictions and with basic theory. The DoE report cites the appended 2023 Santer et al. PNAS paper as "evidence of absence" of a human fingerprint on the vertical structure of atmospheric temperature. Our 2023 paper actually provides strong evidence FOR the positive identification of this human fingerprint in satellite data.

Quote given to Carbon Brief

Supporting evidence

[Link1](#)

5.8 US corn belt

Page 42

FALSE

One of the largest discrepancies between models and observations is in the US corn belt, a region of particular importance to global food production. Figure 5.9 shows the warming trends for summertime (June, July, August) for the 12- state corn belt (IN, IA, IL, ND, SD, MO, MN, WI, MI, OH, KS, NE) during 1973- 2022. All 36 climate models (red) warm far too rapidly compared to observations (blue).

Dr Delphine Deryng, lead author, IPCC AR6 WG2

There is no source for this and no methodological description. I don't believe the comparison between models and observation is correct.

5.8 US corn belt

Page 43

MISLEADING

As discussed in Chapter 9, the anticipated negative effects of increasing temperatures on US corn yields have not materialised, in contrast to widely publicised studies proclaiming that theoretical future impacts are already being experienced (e.g., Seager et al. (2018))

Dr Richard Seager, Ewing Lamont research professor, Columbia University

Our 2018 paper referred to changes in aridity and implications for what crops are grown and farm size and was not about corn yields. We suggest that changes patterns and values of precipitation and potential evapotranspiration would increase aridity over most of the US, which would, in the absence of adaptation, restrict corn cultivation to regions further east. But neither part of the two-part paper claims yields are reducing already due to climate change.

6 Extreme weather

Pages 57-82

MISLEADING*Section 6*

Prof Kerry Emanuel, professor emeritus of atmospheric science, Massachusetts Institute of Technology

The authors begin sensibly, in the introduction, stating that: 'Climate is about the statistical properties of weather over decades, not single events. Further, there are only about 130 years of reliable observational records that can be analysed statistically. That brief interval does not begin to contain all the extreme events that the climate system can create on its own.' It is odd, then, that they proceed to present timeseries of even shorter length and claim not to find trends of extreme events in them, thereby leading the reader to conclude that there are no underlying trends. They should have just stuck with their original statement and made the correct conclusion that observations usually do not suffice to detect extreme event trends of the predicted magnitude, and then turned to an exposition of what theory and models have to say.

It is very odd that there is almost no mention of theory and models [for] extreme events... Global climate data clearly and unequivocally show this bound increasing in virtually all of the tropical cyclone genesis regions. And, contrary to the statement in the DoE report, an upward trend in the proportion of very strong hurricanes HAS been detected and published. But instead of citing any of this, these authors violate their own introductory statement by citing short and generally unreliable records. For example, they state correctly that there is no detectable trend in continental US hurricane landfalls. But at an average of three landfalling storms per year, there are not nearly enough data to detect a trend of the predicted magnitude. Given that the Caribbean region had a high population density (and associated newspaper accounts) going back to the early 19th century, they could have looked at ALL Atlantic landfalls, not just the US. Had they done so, they would have discovered a clear upward trend.

6 Extreme weather

Pages 57-82

MISLEADING*Section 6*

Prof Sonia Seneviratne, head of Institute for Atmospheric and Climate Science, ETH Zurich

The text of chapter 6 often cites chapter 11 of the IPCC AR6, but is a clear example of cherry-picking. The authors repeatedly highlight low-confidence statements from the IPCC AR6 chapter 11 on changes in climate extremes which are mostly on side topics of little relevance, but they rarely cite any high confidence statements from that chapter.

6 Extreme weather

Page 46

MISLEADING

Most types of extreme weather exhibit no statistically significant long-term trends over the available historical record.

Prof Sonia Seneviratne, head of Institute for Atmospheric and Climate Science, ETH Zurich

Importantly, there is no evidence substantiating the claim of the authors of this DOE "critical review" that "most types of extreme weather exhibit no statistically significant long-term trends over the available historical record". It is not clear which types of "extreme weather" the authors refer to, which region(s) they are referring to, and what is the demonstration underlying the claim that "most" of these types exhibit no statistically significant long-term trends. I would ask the authors to provide the arguments substantiating this claim, as there is no rationale provided for this statement in the chapter.

I would also highlight the following conclusions from the IPCC AR6 chapter 11 which provide a very different collective assessment:

- "It is an established fact that human-induced greenhouse gas emissions have led to an increased frequency and/or intensity of some weather and climate extremes since pre-industrial time, in particular for temperature extremes."
- "Human-induced greenhouse gas forcing is the main driver of the observed changes in hot and cold extremes on the global scale (virtually certain)"
- "The frequency and intensity of heavy precipitation events have likely increased at the global scale over a majority of land regions with good observational coverage. Heavy precipitation has likely increased on the continental scale over three continents: North America, Europe, and Asia."
- "More regions are affected by increases in agricultural and ecological droughts with increasing global warming (high confidence)."
- "It is likely that the global proportion of Category 3–5 tropical cyclone instances has increased over the past four decades."

6.2 Temperature extremes

Pages 63-71

MISLEADING

Section 6.3

Prof Erich Fischer, lecturer at the department of environmental systems science, ETH Zurich

The section on hot extremes is an extreme example of cherry-picking results. The report fails to acknowledge that the highlighted regions are some of the very few regions globally where the annual maximum temperatures have not increased (see e.g. IPCC AR6 WG1 Fig. SPM3). The report further highlights that in some regions the number of hottest days have not increased, yet omits that the hottest nights have increased over the same regions and periods (see figure 2.7 in the fifth US National Climate Assessment). Furthermore, the temperature of the warmest nights shows a positive trend over recent decades (Singh et al. 2023). The report further fails to refer to the extensive literature discussing the role of land-use changes and irrigation (Mueller et al. (2016)), aerosol forcing (Mascioli et al. (2017)) and unforced internal variability (Singh et al. (2023)) to the regions with little trends.

Supporting evidence

[Link1](#)

[Link2](#)

[Link3](#)

[Link4](#)

[Link5](#)

6.8 Wildfires

Page 70

MISLEADING

Nonetheless just focusing on the post-1985 interval the number of fires [in the US] is not increasing. The area burned did increase but only until about 2007.

Prof A Park Williams, hydroclimatologist, University of California

The report's section on wildfire lumps the entire US together, smearing out what's going on in the western contiguous US despite the fact that it's the rapidly increasing western US wildfire activity that necessitates this report's wildfire section in the first place. On whether the area burnt in US forest fires has not increased: This is absolutely not the case in the western US, which is again the region that motivates most concerns about wildfire trends in the US. In the western US, the annual area burned has tripled over the past 40 years, driven by a 10-fold increase in annual forest-fire area and a doubling of area burned in non-forest. The western US forest-fire area in 2020 nearly doubled the previous modern record (from 2012) and then 2021 nearly matched 2020. The increase in area burned did not come even close to ending in 2007 in the western US.

On whether fire management practices are responsible for US wildfire trends: Beginning roughly a century ago, the widespread implementation of fire-suppression policies allowed people to effectively take control of wildfire in the western US, but over the past several decades the annual area burned has quickly escalated despite ever intensifying and efforts toward fire suppression. That is, today's concern over wildfire shouldn't depend on how fires of today compare to those of the pre-suppression era, but should instead be related to how the rapidly increasing wildfire sizes in the western US today are occurring despite society's best efforts to avoid such a trend. Further, it's not simply the growing sizes of fires that are of concern. Fire size is simply easy to measure reliably. But as fires have grown larger, they have increasingly put people and property in the paths of flames, had such a negative impact on air quality that trends toward cleaner air since the 1980s have reversed even across much of the eastern US, and rapid increases in the extents of forest area burning at high severities have endangered many forest ecosystems despite fire being a natural ecosystem process."

Quote from external source

7 Changes in sea level

Page 75

FALSE

In evaluating AR6 projections to 2050 (with reference to the baseline period 1995-2014), almost half of the interval has elapsed by 2025, with sea level rising at a lower rate than predicted.

Prof Stefan Rahmstorf, professor of physics of the oceans, University of Potsdam

Possibly they ignored acceleration, an observed fact, thus assuming that in the first half of the period half of the projected rise should have occurred. But, of course, the IPCC projections account for acceleration, so less than half of the rise should have occurred until now. In fact, projecting sea level rise until 2050 just by extrapolating the observed rise, including the observed acceleration, matches almost exactly the IPCC projections even though these are made in a completely different way.

Looking at the data, for the intermediate point 2030, the AR6 predicts a best estimate 9-10cm, relative to the same base period 1995-2014 (Table 9.9 of AR6 WG1). The satellite data show a rise of 74mm from that base period until 2025. At the same rate, that will be 93mm by 2030, well within in the best-estimate prediction.

Quote given to Carbon Brief

7 Changes in sea level

Page 75

FALSE

US tide gauge measurements reveal no obvious acceleration beyond the historical average rate of sea level rise.

Prof Stefan Rahmstorf, professor of physics of the oceans, University of Potsdam

Most US tide gauges show acceleration, on the east coast that is statistically significant and larger than the global average acceleration, on the west coast less so.

Quote given to Carbon Brief

Supporting evidence

[Link1](#)

7.1 Global sea level rise

Page 75

MISLEADING

Following the end of the Little Ice Age in the mid-19th century, tide gauges show that the global mean sea level began rising during the period 1820-1860, well before most anthropogenic greenhouse gas emissions.

Prof Stefan Rahmstorf, professor of physics of the oceans, University of Potsdam

While it is true that that's before "most of" greenhouse gas emissions, it is unfair to compare the "start of" the rise with "most of" emissions. The industrial era is usually assumed to start in 1700 and CO2 concentration

also starts to rise noticeably around 1820-1860, around the same time as sea level (see the Keeling curve).

Quote given to Carbon Brief

8.3 Attribution of global warming

Page 84

MISLEADING

AR6 states that natural external drivers since 1850-1900 have changed global surface temperature by -0.1°C to $+0.1^{\circ}\text{C}$, and internal variability has changed it by -0.2°C to $+0.2^{\circ}\text{C}$ – on average having essentially no net impact on the warming since 1850-1900.

Dr Theodosios Chatzistergos, astrophysicist, Max Planck Institute for Solar System Research

The AR6 report presents this in Fig. SPM.2 as "Aggregated contributions to 2010-2019 warming relative to 1850-1900". This refers to the net effect of various climate drivers on global surface temperature between these two periods, not the maximum changes observed. The accompanying range represents the uncertainty in these estimates. It is therefore misleading to claim that AR6 asserts natural drivers have changed global temperature by $\pm 0.1^{\circ}\text{C}$ since 1850-1900. In reality, Fig. SPM.1 shows that natural variability has led to temperature fluctuations of up to $\pm 0.5^{\circ}\text{C}$ at different times, but the net contribution of natural drivers to long-term warming is estimated at around $\pm 0.1^{\circ}\text{C}$.

8.3 Attribution of global warming

Page 84

MISLEADING

As discussed below, this minimal contribution of natural variability has been disputed by several publications that question the magnitudes of solar variability and internal variability from large-scale ocean circulations.

Dr Theodosios Chatzistergos, astrophysicist, Max Planck Institute for Solar System Research

This claim is supported by only a small number of studies that rely on cherry-picked, outdated, or scientifically implausible TSI reconstructions (e.g., Connolly et al. (2021) and (2023); Scafetta (2023); Soon et al. (2023); Grok et al. (2025); and Green and Soon (2025)). All of these studies rely heavily on the Hoyt and Schatten (1993) TSI series, which has been extensively criticised and discredited by Chatzistergos (2024) for its arbitrary adjustments, methodological flaws and use of fabricated data. As such, these claims do not reflect a broadly accepted scientific view. The review by Chatzistergos et al. (2023) provides a comprehensive and up-to-date overview of our current understanding of long-term solar irradiance variations and also explains why the practices underlying such claims are scientifically flawed. I note that although the Chatzistergos et al. (2023) review is cited in the DoE report, it is referenced for an unrelated and irrelevant reason and its core content is disregarded.

8.3 Attribution of global warming

Page 84

MISLEADING

AR5 concluded that the best estimate of radiative forcing due to Total Solar Irradiance (TSI) changes over the period 1750–2011 was very small (0.05 W/m², Myrhe et al. (2014)).

Dr Theodosios Chatzistergos, astrophysicist, Max Planck Institute for Solar System Research

This is an example of imprecise wording that could be misleading. In AR5, the solar radiative forcing difference between the 1745 and 2008 activity minima was estimated using TSI reconstructions from Wang et al. (2005), Steinhilber et al. (2009) and Krivova et al. (2010). These studies yielded a range of -0.02 to 0.071 Watts per metre squared (W/m²) for the difference (based on seven-year running means, with the caveat that the -0.02 W/m² value comes from Steinhilber et al. (2009), which has a five-year resolution and uses 1965 as the minimum). Based on these estimates, AR5 adopted a range of 0-0.1 W/m² with a central estimate of 0.05 W/m², as explicitly stated in Table 8.SM.4 of the report. However, AR6 defined solar forcing in a different way to reflect the difference between full solar cycles rather than solar minima, as noted in chapter 7 of the WG1 report. This change in methodology is not acknowledged in the DoE report, which may lead to misunderstandings or incorrect comparisons between AR5 and AR6 values.

8.3 Attribution of global warming

Page 84

MISLEADING

AR6 acknowledges substantially higher values and a much larger range of estimates of changes in TSI over the last several centuries, stating that the TSI between the Maunder Minimum (1645-1715) and the second half of the 20th century increased by 0.7–2.7 W/m², a range that includes both low and high variability TSI data sets (Gulev (2021)).

Dr Theodosios Chatzistergos, astrophysicist, Max Planck Institute for Solar System Research

The sentence is vague (in particular as to what they refer with "higher values") and potentially conflates two related but distinct concepts: radiative forcing and TSI differences, which were both mentioned but not clearly distinguished. Considering that the previous sentence discusses radiative forcing, one can assume that with "higher values" they refer to radiative forcing too, which would make the statement false. This is easily understood by comparing the statements in AR6 and AR5 about the range of solar radiative forcing.

The AR6 WG1 report (page 958) states:

"In contrast to AR5, the solar effective radiative forcing (ERF) in this assessment uses full solar cycles rather than solar minima. The pre-industrial TSI is defined as the mean from all complete solar cycles from the start of the 14C SATIRE-M proxy record in 6755 BCE to 1744 CE. The mean TSI from solar cycle 24 (2009–2019) is adopted as the assessment period for 2019. The best estimate solar ERF is assessed to be 0.01 W/m², using the 14C reconstruction from SATIRE-M, with a likely range of -0.06 to +0.08 W/m² (medium confidence). The uncertainty range is adopted from the evaluation of Lockwood and Ball (2020), who performed a Monte Carlo analysis of solar activity from the Maunder Minimum to 2019 using several datasets, resulting in an ERF range of -0.12 to +0.15 W/m². The Lockwood and Ball (2020) full uncertainty range is halved since the period of reduced solar activity in the Maunder

Minimum had ended by 1750 (medium confidence)." By comparison, the AR5 WGI report (page 689) states: "The best estimate from our assessment of the most reliable TSI reconstruction gives a seven-year running mean radiative forcing (RF) between the minima of 1745 and 2008 of 0.05 W/m². Our assessment of the range of RF from TSI changes is 0.0 to 0.10 W/m²."

Thus, the solar radiative forcing estimates in AR5 and AR6 are broadly consistent, with AR6's best estimate slightly lower. If the statement instead refers to TSI differences, this would also be misleading. The AR6 WGI (page 297) lists a TSI difference between the Maunder Minimum and the second half of the 20th century ranging from 0.7 to 2.7 W/m². The lower bound likely corresponds to the SATIRE-T reconstruction, while the upper bound comes from the Yeo et al. (2020) constraint on the dimmest possible state of the sun. It is important to note that Yeo et al. (2020) does not reconstruct TSI during the Maunder Minimum but rather provides a theoretical constraint on the minimum plausible solar irradiance. This constraint effectively excludes TSI reconstructions with large amplitude variability, such as Egorova et al. (2018).

Almost all current TSI reconstructions indicate significantly smaller long-term TSI trends (Chatzistergos et al. (2023)). These include the SATIRE and NRL (now NNL) models recommended for CMIP6 and AR6.

8.3 Attribution of global warming

Page 84

FALSE

The IPCC has only minimally discussed solar influences on global and regional climate.

Prof Mike Lockwood, professor of space environment physics and president of the Royal Astronomical Society, University of Reading

Contrary to this statement, there is much discussion in the last three IPCC assessment reports.

8.3 Attribution of global warming

Page 85

MISLEADING

There is substantial evidence for high solar activity in the second half of the 20th century (starting in 1959) and extending into the 1990s, before a decline in the early 21st century; this period is often termed the "Modern Maximum" (Chatzistergos et al. (2023); Solanki et al. (2004); Usoskin et al. (2007)). However, some scientists have concluded that it is not possible to be confident of any multi-decadal trend in TSI (Schmutz (2021)).

Theodosios Chatzistergos, astrophysicist, Max Planck Institute for Solar System Research

"Although the sentence in which they cite us is factually accurate in isolation, the surrounding text creates a misleading impression. More importantly, our review paper, which they cited, explains why their subsequent paragraph has misleading and wrong statements."

Quote from external source

8.3 Attribution of global warming

MISLEADING

However, the recommended forcing dataset for the CMIP6 climate model simulations used in AR6 for attribution studies averages two data sets with low solar variability (Matthes (2017)).

Dr Theodosios Chatzistergos, astrophysicist, Max Planck Institute for Solar System Research

interpreted as an actual historical TSI difference between the Maunder Minimum and the present, but rather as a physical upper bound on the maximum plausible difference between the sun's dimmest possible state and its current irradiance. Importantly, the Maunder Minimum is unlikely to represent this dimmest state and modern TSI reconstructions suggest a substantially smaller long-term trend than what a 2.7 W/m² Maunder-to-present difference would imply. This upper limit, derived from Yeo et al. (2020), effectively excludes high-variability TSI reconstructions that exceed this threshold. For this reason, the CMIP6 and IPCC AR6 selected two TSI reconstructions, SATIRE (Yeo et al. (2014) and Wu et al. (2018)) and NRLTSI (now referred to as NNLTSI, Coddington et al. (2016), not based on their implied variability magnitude, but because they represent the most advanced, scientifically robust, and rigorously validated models currently available (Matthes et al. (2017)). SATIRE is a semi-empirical, physics-based model, whereas NRLTSI is a proxy-based regression model. Both have undergone extensive scrutiny and show excellent agreement with direct satellite measurements of TSI.

8.3 Attribution of global warming**MISLEADING**

While AR6 shows a substantially greater solar impact than does AR5, the overall impact of solar forcing on the climate was still assessed to be small compared to anthropogenic forcing.

Dr Theodosios Chatzistergos, astrophysicist, Max Planck Institute for Solar System Research

The statement is vague and unclear in what it means by “AR6 shows a substantially greater solar impact than AR5”, especially since the same sentence acknowledges that solar forcing was assessed to be small compared to anthropogenic forcing, implying a correspondingly small solar impact. This apparent contradiction likely stems from confusion on the part of the DoE authors regarding the distinction between radiative forcing and total solar irradiance (TSI) differences as presented in AR5 and AR6, as discussed in previous comments.

Quote given to Carbon Brief

8.3 Attribution of global warming**MISLEADING**

However, the impact of solar variations on the climate is uncertain and subject to substantial debate (Lockwood (2012); Connolly et al. (2021)) - something that is not evident in the IPCC assessment reports.

Dr Theodosios Chatzistergos, astrophysicist, Max Planck Institute for Solar System Research

AR6 acknowledges the high-variability reconstruction by Egorova et al. (2018) and references studies by Yeo et al. (2020) and Lockwood & Ball (2020), discussing the inherent uncertainty in estimating the secular trend in solar irradiance variations. The earlier study by Lockwood (2012) is not included because its findings are superseded by the more recent Lockwood & Ball (2020). Mike Lockwood was actually one of the contributors to AR6. Thus, IPCC AR6 did adequately discuss the existing uncertainty in irradiance modelling and, thus, its effects on Earth's climate. However, what the authors of the DoE report seem to mean with this sentence is that AR6 does not discuss the Connolly et al. (2021) study. It is worth repeating that the Connolly et al. (2021) paper gave a misleading presentation of the literature. In particular, Connolly et al. (2021) cherry-picked 16 TSI reconstructions, deliberately balancing the sample by including eight with small long-term trends and eight with pronounced trends. However, their inclusion of several outdated or discredited models within the high-variability group is misleading, particularly given the DoE chapter summary's claim that all selected reconstructions are plausible (Chatzistergos et al. (2023) and Chatzistergos (2024)).

As noted in previous comments, the issues with Connolly et al. (2021) undermine the credibility of their results. While there is legitimate uncertainty about the exact magnitude of long-term solar irradiance trends, Connolly et al. (2021) exaggerated the solar impact by cherry-picking outdated and superseded series that display implausibly large TSI variations.

8.3 Attribution of global warming

Page 85

MISLEADING

There are several rival composite TSI datasets that disagree as to whether TSI increased or decreased during the period 1986-96.

Dr Theodosios Chatzistergos, astrophysicist, Max Planck Institute for Solar System Research

It is also important to note that the effect of ACRIM-gap in the trends of the different TSI composites is generally small (Chatzistergos et al. (2023) and Kopp (2025)). While the issue with ACRIM does contribute to the uncertainty in the long-term trend of direct TSI measurements, a growing body of evidence challenges the notion of a TSI increase during the ACRIM-gap, evidence which the DoE report entirely overlooks. Notable examples include Amdur & Huybers (2023), Chatzistergos et al. (2025) and Krivova et al. (2009). By having given such emphasis on the ACRIM-gap the DoE report gives the misleading impression that there can be significant increase in TSI, which could account for the global warming over the same period. Thus, this statement can be misleading.

8.3 Attribution of global warming

Page 85

MISLEADING

Further, the satellite record of TSI is used to calibrate proxy models that infer past solar variations from sunspots and cosmogenic isotope measurements (Velasco Herrera et al. (2015)).

Dr Theodosios Chatzistergos, astrophysicist, Max Planck Institute for Solar System Research

There are several issues with this sentence, particularly concerning the choice of the sole reference, which may mislead readers into believing that existing total solar irradiance (TSI) reconstructions depend heavily on direct TSI measurements for determining long-term trends. This is generally incorrect. Moreover, the phrasing gives the impression that only proxy models exist, overlooking the important class of physics-based semi-empirical models

1) Missing relevant literature: The statement omits key papers on irradiance reconstruction models (e.g., Coddington et al. (2016); Wu et al. (2018); and Chatzistergos et al. (2024)) and authoritative reviews (e.g., Chatzistergos et al. (2023) and (2024); and Solanki et al. (2013)) that provide a more accurate and comprehensive perspective.

2) Choice of reference: The DoE cites only Velasco Herrera et al. (2015) to support the claim, which is problematic. That work is not an irradiance reconstruction model but a machine learning extrapolation inherently dependent on the chosen TSI reference series. Given the chaotic nature of solar activity, such extrapolations from limited data lack scientific merit (see Petrovay (2020)). Moreover, the predictions from Velasco Herrera et al. (2015) for 2015–25 are already contradicted by actual direct TSI measurements obtained since.

1) Proxy models: These reconstruct irradiance variations by scaling or regressing solar activity indices against reference TSI data. While the choice of reference series can influence results depending on the regression method, the effect is not always big. For example, Chatzistergos et al. (2020) demonstrated that the choice of TSI reference has negligible impact on minimum-to-minimum trends in their regression model. Similarly, Figure 7c in Chatzistergos et al. (2024) shows only a minor effect of different TSI references on their century-long TSI reconstruction.

2) We have not only proxy models but also physics-based semi-empirical models. Models such as SATIRE and SRPM do rely on tuning some free parameters by comparison to direct TSI measurements. However, this tuning does not significantly affect the long-term trends, as shown in multiple studies (e.g., Chatzistergos et al. (2021)). Notably, Chatzistergos et al. (2025) explicitly states about their irradiance reconstruction with SATIRE-S that "the trend in the updated SATIRE-S TSI composite is independent of measured TSI".

8.3 Attribution of global warming

Page 85

MISLEADING

There is substantial evidence for high solar activity in the second half of the 20th century (starting in 1959) and extending into the 1990s, before a decline in the early 21st century; this period is often termed the "Modern Maximum." (Chatzistergos et al. (2023); Solanki et al. (2004); Usoskin et al. (2007))

Dr Theodosios Chatzistergos, astrophysicist, Max Planck Institute for Solar System Research

The citation of Chatzistergos et al. (2023) in support of the statement about the "Grand Modern Maximum" of solar activity is somewhat misleading. First, the cited paper is a review focused specifically on solar irradiance modeling and long-term trends in irradiance reconstructions. The Grand Modern Maximum is

mentioned only briefly in the introduction and is not a subject of analysis in the paper. Moreover, the concept of the Grand Modern Maximum is primarily based on direct sunspot observations, as discussed in works such as Chatzistergos et al. (2017) and Usoskin et al. (2016), which is clearly stated in Chatzistergos et al. (2023), but omitted in the DoE report. The other two studies cited in the DoE, Solanki et al. (2004) and Usoskin et al. (2007), inferred this period in sunspot number series reconstructed from cosmogenic isotope data.

However, these data do not cover the full extent of the modern maximum, and the connection between isotope-based and direct sunspot records remains uncertain. Recent reconstructions like Wu et al. (2018; where both Sami K. Solanki and Ilya G. Usoskin are co-authors) continue to support the existence of a Grand Modern Maximum, but suggest it was less pronounced than earlier assumed.

I presume the authors do not include this study because it was used to reconstruct irradiance variations and returned a rather small secular trend, which would conflict with the claim they want to make here. It is important to recognise that elevated sunspot activity during the second half of the 20th century does not, on its own, determine how much solar irradiance increased, as information on faculae is also essential. Irradiance variations are driven not only by sunspots but also by faculae and network magnetic features. Unfortunately, direct facular observations only extend back to 1892, and their use prior to the 1970s has been rather limited. Consequently, reconstructing past irradiance variations requires assumptions about the relationship between sunspots and faculae, which introduces uncertainty into estimates of the secular trend. However, recent efforts to extract facular information from Ca II K observations (e.g., Chatzistergos et al. (2024)) and to extend irradiance reconstructions back to 1892 indicate only a minimal long-term trend over the 20th century, consistent with state-of-the-art reconstructions such as SATIRE. As mentioned above also updated reconstructions with cosmogenic isotope data (Wu et al. (2018)) suggest a rather small long-term trend. None of this McKittrick (2025) re-examined the Moore et al. database and found that, while it claimed to cover 1,722 studies, only half the entries (N=862) had complete context is provided in the DoE report, resulting in a potentially oversimplified or overstated implication that a large secular trend is more likely, despite the balance of current evidence.

8.3 Attribution of global warming

Page 85

MISLEADING

However, some scientists have concluded that it is not possible to be confident of any multi-decadal trend in TSI (Schmutz, 2021).

Dr Theodosios Chatzistergos, astrophysicist, Max Planck Institute for Solar System Research

This statement is misleading because it refers to section 3 of Schmutz (2021), which focuses on direct measurements of solar irradiance only since 1978, whereas the DoE report in the previous sentence was discussing the grand modern maximum and thus longer-term trends beyond the period covered by direct TSI measurements. Furthermore, the uncertainty in determining the long-term trend, both from direct measurements and modeled reconstructions, is widely acknowledged in the scientific literature and is not limited to a small group of scientists. Nevertheless, all current evidence and advances consistently indicate a relatively weak secular trend in total solar irradiance (TSI) variations.

Quote given to Carbon Brief

8.3 Attribution of global warming

MISLEADING

This uncertainty causes some reconstructions of TSI from 1750 to have low variability (implying a very low impact of solar variations on global mean surface temperature) whereas datasets with high TSI variability can explain more than 70% of the temperature variability since pre-industrial times (Scafetta (2013); Stefani (2021)).

Dr Theodosios Chatzistergos, astrophysicist, Max Planck Institute for Solar System Research

Neither of the two papers cited for the claim that "datasets with high TSI variability can explain more than 70% of the temperature variability since pre-industrial times". Stefani (2021) did not even use any TSI series; instead, he performed a linear regression between the geomagnetic aa-index and sea surface temperature. Scafetta (2013, p27) states: "Figure 15B compares the Central England Temperature (CET) record and the TSI model by Hoyt and Schatten plus the ACRIM TSI record; an overall good correlation is observed since 1700, which suggests that the major observed climatic oscillations are solar induced and that the sun explains about 50-60% of the warming observed since 1900."

This raises two major concerns. First, the statement in the report is incorrect since neither Scafetta (2013) nor Stefani (2021) demonstrate that TSI can account for "more than 70% of the temperature variability since preindustrial times". Second, the conclusion by Scafetta (2013) relies on the Hoyt and Schatten (1993) TSI model after connecting it to the ACRIM TSI composite. The Hoyt and Schatten 1993 TSI model has been shown to be highly unrealistic and is now widely discredited (Chatzistergos (2024)). As detailed in Chatzistergos (2024), the Hoyt and Schatten model includes multiple arbitrary adjustments and fabricated data for one index spanning over a decade, which appear to have been copied from another index. Critically, the model's high variability was not a result of the model but was imposed by the authors. When updated underlying indices and direct TSI composites (e.g., PMOD, Montillet et al. (2022), ACRIM) are considered, it becomes clear that Hoyt and Schatten (1993) exaggerated TSI variation amplitudes by roughly a factor of five (Chatzistergos (2024)). The discrepancy is even greater when compared to the ACRIM TSI composite, which Hoyt and Schatten's model is incompatible with. This seriously undermines the reliability of conclusions drawn from the Hoyt and Schatten model for attributing recent climate change to solar variability.

Therefore, the two given references do not corroborate the claim of the DoE report. This statement likely originates from Connolly et al. (2023), but the same criticisms previously discussed regarding Connolly et al. (2021) apply here as well. Connolly et al. (2021) and (2023) cherry-picked TSI reconstructions to amplify several outdated or discredited models with high secular trends. As noted in previous comments, these issues undermine the credibility of their results. While there is legitimate uncertainty about the exact magnitude of long-term solar irradiance trends, Connolly et al. (2021) and (2023) exaggerated the solar impact by cherry-picking outdated and superseded series that display implausibly large TSI variations.

8.3 Attribution of global warming**MISLEADING**

The choice of TSI satellite record used in an analysis can therefore substantially influence how much climate change is attributed to human versus natural forcings.

Dr Theodosios Chatzistergos, astrophysicist, Max Planck Institute for Solar System Research

This statement is misleading and confusing. First, the choice of TSI satellite record does not substantially influence the estimated solar contribution to climate change; rather, it is the choice of modelled TSI series, which was the topic of the previous sentence, that can have an impact. Second, as explained above, the high-variability TSI reconstructions used by Connolly et al. (2021) and (2023) to attribute most warming to the Sun are outdated, superseded, and scientifically implausible. While there is indeed uncertainty regarding the long-term trend in solar irradiance, which naturally affects the precise estimate of solar-driven global warming, all current evidence indicates this contribution is relatively small. The sentence in the DoE report, however, dramatically exaggerates this uncertainty and its implications.

However, it is also possible that the authors of the DoE report intended to suggest that the choice of TSI satellite records influences the reconstruction outcomes and thus the estimated solar contribution to global warming. This interpretation would also be misleading, as explained earlier, but reiterated here:

- 1) While the choice of reference TSI series can affect proxy model results depending on the regression approach, this effect is often small. For example, Chatzistergos et al. (2020) demonstrated that the choice of TSI reference has a negligible impact on minimum-to-minimum trends in their regression model. Similarly, Figure 7c in Chatzistergos et al. (2024) shows only minor differences when using various TSI references in their century-long reconstruction.
- 2) This effect is typically negligible in physics-based semi-empirical models. Various studies have confirmed the minimal impact on SATIRE reconstructions when changing the reference TSI series (e.g., Chatzistergos et al. 2021). Notably, for the latest version of SATIRE-S, Chatzistergos et al. (2025) explicitly state that "the trend in the updated SATIRE-S TSI composite is independent of measured TSI".
- 3) As mentioned earlier, the DoE authors cited Velasco Herrera et al. (2015) instead of irradiance reconstruction models, which may have caused the confusion. Velasco Herrera et al. (2015) presented a machine learning extrapolation that inherently depends on the chosen TSI reference series. Given the chaotic nature of solar activity, such limited-data extrapolations lack scientific robustness (see Petrovay (2020)). Moreover, Velasco Herrera et al. 2015 predictions for 2015-25 have already been contradicted by direct TSI measurements collected since.

8.3 Attribution of global warming

Page 85

FALSE

Scafetta et al. (2023) suggests that ~80% of solar influence on climate might stem from non-TSI mechanisms.

Dr Theodosios Chatzistergos, astrophysicist, Max Planck Institute for Solar System Research

The reference is incorrect, there is no Scafetta et al. (2023); this should be Scafetta (2023). Although Scafetta (2023) indeed makes this claim, it is yet another such claim of attributing most global warming to the sun mainly based on the use of the discredited Hoyt and Schatten (1993) TSI series (Chatzistergos (2024)). Scafetta (2023) bases his analysis on a combination of three TSI series: Hoyt and Schatten (1993), Egorova et al. (2018) and the one recommended by CMIP6. Since the Hoyt and Schatten (1993) TSI series was not updated prior to Chatzistergos (2024), Scafetta extended it by linking it to the ACRIM TSI composite. Chatzistergos (2024) demonstrated that the high variability imposed by Hoyt and Schatten (1993) is

inconsistent with direct TSI measurements and that a variability magnitude approximately five times smaller is required.

Additionally, Chatzistergos (2024) showed that the Hoyt and Schatten (1993) model conflicts particularly with the ACRIM composite by exhibiting opposite trends during the so-called ACRIM-gap, making Scafetta's extension of Hoyt and Schatten (1993) with ACRIM invalid. Thus, with Egorova et al. (2018) exceeding the Yeo et al. (2020) physical constraint, and considering the multiple methodological issues identified with the Hoyt and Schatten (1993) series (Chatzistergos (2024)), the resulting conclusions by Scafetta (2023) are unlikely. Furthermore, Scafetta himself acknowledged that even when allowing for solar effects beyond radiative forcing, the solar influence remains minimal with the CMIP6 TSI forcing. Therefore, the claim that solar influence accounts for more than 80% of warming is unsupported.

Quote given to Carbon Brief

8.3 Attribution of global warming

Page 85

MISLEADING

There are numerous candidate processes, including solar ultraviolet changes; energetic particle precipitation; atmospheric-electric-field effect on cloud cover; cloud changes produced by solar-modulated galactic cosmic rays; large relative changes in the magnetic field; and the strength of the solar wind. Such solar indirect effects are not included in climate models, although indirect methods of estimating their impacts suggest they are significant.

Dr Theodosios Chatzistergos, astrophysicist, Max Planck Institute for Solar System Research

It is exaggerated and incorrect to claim that the impacts of such effects are significant. Many of these effects are described vaguely in the DoE report, making their implications unclear (for example, "large relative changes in the magnetic field") without specifying what that entails. Additionally, the influence of cosmic rays on cloud formation has been shown to be negligible, as demonstrated by the CLOUD experiment at CERN (Pierce (2017)). While some effects on Earth's atmosphere from other processes have been studied (e.g., Mironova et al. (2015) and Sinnhuber & Funke (2020)), their effects are generally considered to be small.

8.3 Attribution of global warming

Page 85

MISLEADING

However, the recommended forcing dataset for the CMIP6 climate model simulations used in AR6 for attribution studies averages two data sets with low solar variability (Matthes, (2017)).

Prof Mike Lockwood, professor of space environment physics and president of the Royal Astronomical Society, University of Reading

The statement is true, but very misleading as it is made to sound that larger TSI-drift papers were ignored. There is only one very high TSI drift reconstruction and it is very much an outlier – other reconstructions

show much smaller drift. There is also analysis of recent solar cycles that shows that the low TSI change reconstructions are correct.

8.3 Attribution of global warming

MISLEADING

However, the impact of solar variations on the climate is uncertain and subject to substantial debate (Lockwood (2012); Connolly et al. (2021)) – something that is not evident in the IPCC assessment reports.

Prof Mike Lockwood, professor of space environment physics and president of the Royal Astronomical Society, University of Reading

This is highly misleading as it conflates regional and global climate. The cited references were discussing regional climates where there is more uncertainty and some (limited) solar influence through downward propagation of stratospheric responses, especially in winter. The global climate is not open to such uncertainty. The cooling (as opposed to warming) of the global stratosphere shows conclusively that the effect of solar change on the global climate is minimal compared to effects of changing solar irradiance.

8.3 Attribution of global warming

Page 85

MISLEADING

However, the recommended forcing dataset for the CMIP6 climate model simulations used in AR6 for attribution studies averages two data sets with low solar variability solar variability (Matthes (2017)).

Prof Katja Matthes, director, GEOMAR Helmholtz Centre for Ocean Research Kiel

It is correct that the long-term trend in TSI is rather on the low variability side, but it is completely ignored that other more extreme trends (high variability trends) are completely unrealistic. We only provide an extreme Maunder Minimum case as a sensitivity experiment.

8.3 Attribution of global warming

Page 85

MISLEADING

While AR6 shows a substantially greater solar impact than does AR5, the overall impact of solar forcing on the climate was still assessed to be small compared to anthropogenic forcing. However, the impact of solar variations on the climate is uncertain and subject to substantial debate

(Lockwood (2012); Connolly et al. (2021) – something that is not evident in the IPCC assessment reports. The variations of TSI over time remains a challenging problem. Since 1978, there have been direct measurements of TSI from satellites. However, the data exhibits non-negligible inconsistencies, and interpreting any multi-decadal trends in TSI requires comparisons of observations from overlapping satellites. There are several rival composite TSI datasets that disagree as to whether TSI increased or decreased during the period 1986-96 (the ACRIM gap; see Chapter 4). Further, the satellite record of TSI is used to calibrate proxy models that infer past solar variations from sunspots and cosmogenic isotope measurements (Velasco Herrera et al. (2015)). There is substantial evidence for high solar activity in the second half of the 20th century (starting in 1959) and extending into the 1990s, before a decline in the early 21st century; this period is often termed the "Modern Maximum". (Chatzistergos et al. (2023); Solanki et al. (2004); Usoskin et al. (2007)). However, some scientists have concluded that it is not possible to be confident of any multi-decadal trend in TSI (Schmutz (2021)). This uncertainty causes some reconstructions of TSI from 1750 to have low variability (implying a very low impact of solar variations on global mean surface temperature) whereas datasets with high TSI variability can explain more than 70% of the temperature variability since pre-industrial times (Scafetta (2013); Stefani (2021)). The choice of TSI satellite record used in an analysis can therefore substantially influence how much climate change is attributed to human versus natural forcings.

Prof Katja Matthes, director, GEOMAR Helmholtz Centre for Ocean Research Kiel

In Matthes et al. (2017), we conclude the following two points (just as an example of mis-citation):

- 1) A new and lower TSI value is recommended: the contemporary solar-cycle average is now 1,361.0 +/- 0.5 W/m² (Prša et al. (2016)).
- 2) Over the last three solar cycles in the satellite era, there is a slight negative TSI trend in the CMIP6 dataset. A recent reconstruction of the TSI, with a proper estimation of its uncertainties, suggests that this downward trend between the solar minima of 1986 and 2009 is not statistically significant (Dudok de Wit et al. (2017)). The TSI trend leads to an estimated radiative forcing on a global scale of -0.04 W/m², which is small in comparison with other forcings over this period.

Therefore the sentence in the DoE report stating that the "choice of TSI satellite record used in an analysis can therefore substantially influence how much climate change is attributed to human versus natural forcings" is completely wrong and ignores the thorough science. The radiative forcing to this natural forcing – even if we would have chosen a different TSI dataset – is small (-0.04 W/m²).

The next completely wrong statement is that "such solar indirect effects are not included in climate models". In Matthes et al. (2017), we provide a comprehensive dataset including TSI and solar spectral irradiance data as well as solar particle forcing for the first time. We also provide an ozone dataset with the indirect effect included. Many of the CMIP6 models do include spectral solar irradiance as well as ozone changes, so the indirect effect and some even the particle effects. I am really shocked about these wrong statements. The IPCC is based on sound scientific evidence and this DoE report is kicking the evidence with feet. Misinterpreting and mis-citing or not at all citing important work (such as the important parts of Matthes et al. (2017) where we provide sound scientific evidence and discuss the details) – this is just horrible. By taking out only parts of the story and "simplifying it", it is becoming simply wrong. This is not sound science."

8.4 Declining planetary albedo and recent record warmth

Page 90

MISLEADING

Arguably the most striking change in the Earth's climate system during the 21st century is a significant reduction in planetary albedo since 2015, which has coincided with at least two years of record global warmth. Figure 8.2 shows the planetary albedo variations since 2000, when there are good satellite observations. The 0.5% reduction in planetary albedo since 2015 corresponds to an increase of 1.7 W/m² in absorbed solar radiation averaged over the planet (Hansen and Karecha (2025)). For comparison, Forster et al. (2024) estimate the current forcing from the increase in atmospheric CO₂ compared to pre-industrial times to be 2.33 W/m².

Prof Piers Forster, professor of climate physics, University of Leeds

[The citation] is correct, but it presents a somewhat incomplete comparison with the absorbed solar radiation. One's a very long-term forcing, the other is a mix of forcing and response over a shorter period, so the two numbers are not very comparable. All Earth's energy budget terms need to be considered and understood together. And when all components are analysed together, the cause of the Earth's energy balance can be traced to GHG warming and the Earth's system response with a good degree of certainty, as explained by theHodnebrog et al. (2024) paper already referenced. This text as written is ok, but for me it plays up the uncertainties somewhat.

8.4 Declining planetary albedo and recent record warmth

Page 90

FALSE

Arctic sea ice extent has declined by about 5% since 1980

Anonymous

September sea ice (1979-88 average compared to 2015-24 average) is 34% lower today according to OSISAF [Ocean and Sea Ice Satellite Application Facility] observations and 35% lower according to NSIDC [National Snow and Ice Data Center]. For the annual mean sea ice extent, the percentage reduction is 14% according to NSIDC and OSISAF. The number is higher in summer because that is when there is the most sea ice loss and the seasonal minimum, so the least amount to start with. In addition, the evidence given to support this statement links to a figure showing sea ice decline in Antarctica in July.

8.4 Declining planetary albedo and recent record warmth

Page 90

MISLEADING

...although following 2007 there has been a pause in the Arctic sea ice decline (England et al. (2025)).

Anonymous

What they say is true and is correctly cited, but lacking context. In the latest version published recently [the DoE report cites a preprint version], the authors note that they “find that the existence of this slowdown also predisposes the sea ice cover for a more rapid decline in the near future”. They add that they “would like to

underscore that pause or slowdown are used interchangeably to refer to an extended period with little or no decline in sea ice cover, due to the observed realisation of multi-decadal climate variability on top of the response to anthropogenic forcing, temporarily interrupting the ongoing long-term reduction in Arctic sea ice. This does not imply a cessation of human-induced climate change and, instead, it is likely that sea ice would have increased over this period without human influence.”

8.4 Declining planetary albedo and recent record warmth

Page 90

MISLEADING

Regarding Antarctic sea ice, the IPCC AR6 concludes that “There has been no significant trend in Antarctic sea ice area from 1979 to 2020 due to regionally opposing trends and large internal variability.” (Summary for Policymakers, A.1.5)

Anonymous

While this is true, it is misleading because they neglect to mention that Antarctic sea ice cover has had a dramatic decline since 2015 and the last few years have seen record lows. Studies have found that these record lows were unlikely to have happened before over the last century. Missing out the last few years of Antarctic sea ice trajectory is a huge omission.

8.4 Declining planetary albedo and recent record warmth

Pages 101-103

MISLEADING

Section 8.4

Dr Helge F. Goessling, climate physicist and group leader, Alfred Wegener Institute

The authors manage to avoid statements that are individually clearly wrong. It is even somewhat difficult to nail down individual sentences that would be clearly misleading taken alone, because that depends on the context they are placed in. However, considering the section as a whole, I think it's pretty clear that they are over-emphasising uncertainties and the possible relative role of natural variability while down-playing the two other main possible mechanisms behind the albedo decline of the last two and a half decades, namely a possibly emerging positive low-cloud feedback and (largely indirect) aerosol effects.

8.4 Declining planetary albedo and recent record warmth

Pages 101-103

MISLEADING

Section 8.4

Prof Richard Allan, professor of climate science, University of Reading

I did not spot major errors in the section on planetary albedo, although I consider that there is an emphasis on abruptness of temperature and albedo changes, which artificially emphasise the role of natural variability. which could be misleading.

8.4 Declining planetary albedo and recent record warmth

Page 90

MISLEADING

A sharp recent increase in global average temperatures has raised the question of short-term drivers of climate. One such candidate is the fraction of absorbed solar radiation which has also increased abruptly in recent years. The question is whether the change is an internal feedback to warming caused by greenhouse gases, or whether something else increased the fraction of absorbed radiation which then caused the recent warming.

Prof Richard Allan, professor of climate science, University of Reading

A "sharp recent increase in global temperature" and "the fraction of absorbed solar radiation which has also increased abruptly" are potentially misleading since while both global surface temperature and absorbed solar radiation have varied with ENSO, they have also increased steadily over time (Loeb et al. (2024) and Forster et al. (2024)). This wording could artificially emphasise the role of natural variability.

8.4 Declining planetary albedo and recent record warmth

Page 90

MISLEADING

Arguably the most striking change in the Earth's climate system during the 21st century is a significant reduction in planetary albedo since 2015, which has coincided with at least two years of record global warmth.

Prof Richard Allan, professor of climate science, University of Reading

Planetary albedo has decreased before 2015 as well as after, though the decreases are larger around 2012-14 (increases in absorbed sunlight in Loeb et al. (2024), Fig. 5a). Decreases in reflected sunlight up to 2016 are captured by some climate models applying observed SST (Loeb et al. (2020)), suggesting that they are a response to global warming and its spatial pattern (Andrews et al. (2022)), though it is not clear how much of the pattern of global warming is explained by radiative forcing and how much internal variability.

8.4 Declining planetary albedo and recent record warmth

Page 91

MISLEADING

The issue then becomes the cause of the change in cloud cover. Two explanations have been posited for the declining cloud cover over the past decade: • Natural climate variability • Changes in

low cloud cover associated with warming sea surface temperatures, implying an emerging positive feedback to climate change (Hansen and Karecha (2025))

Dr Helge F. Goessling, climate physicist and group leader, Alfred Wegener Institute

Maybe even more importantly, they omit the third major possible mechanism behind the cloud-cover decline altogether, namely indirect aerosol effects. They do mention aerosols and recent aerosol emission reductions, but only prior to the part where they state that the main reason for the albedo-decline seems to be related to clouds (which, by itself, is true). They write: "The issue then becomes the cause of the change in cloud cover. Two explanations have been posited for the declining cloud cover over the past decade." However, the indirect aerosol effect, although uncertain, is likely even stronger than the direct aerosol effect, and it is an important candidate for explaining a part of the recent cloud-cover decline. By omitting this completely, they further emphasise the relative importance of natural variability to a degree that can not be considered appropriate.

Quote given to Carbon Brief

8.4 Declining planetary albedo and recent record warmth

Page 91

MISLEADING

Surface albedo changes have thus contributed only weakly to the recent planetary albedo decline, particularly when averaged annually and globally.

Prof Richard Allan, professor of climate science, University of Reading

Surface albedo has also contributed significantly to the decline in global albedo according to Loeb et al. (2024), which accounts for cloud masking: "...part of the positive –SW trend is impacted by decreases in surface albedo from declining sea-ice coverage during the CERES period". However, this applies to the period since 2000, rather than during 2015, which line 10 [of the DoE report] is referring to, while the decrease in planetary albedo has been observed over the full CERES period rather than just in 2015 (Loeb et al. (2024)).

8.4 Declining planetary albedo and recent record warmth

Page 91

MISLEADING

Loeb et al. found that decreases in low- and mid-level clouds since 2015 are the primary reason for decreasing planetary albedo in the northern hemisphere, whereas in the southern hemisphere the decrease in planetary albedo is primarily due to decreases in mid-level clouds across all latitude zones.

Prof Richard Allan, professor of climate science, University of Reading

The stated "decreases in low- and mid-level clouds" is misleading since Loeb et al. (2024) find decreases in cloud cover and also reflectance have contributed to the increase in absorbed sunlight along with surface albedo decreases (that can be related to ice melt elsewhere in the article): "[W]e find that decreases and middle cloud fraction and reflection and reduced reflection from cloud-free areas in mid-high latitudes are the primary reasons for increasing ASR [absorbed solar radiation] trends in the [northern hemisphere]...In the [southern hemisphere] the increase in ASR is primarily from decreases in middle cloud reflection and a weaker reduction in low-cloud reflection." The increase in reflection counters arguments presented that the decreases in aerosol are not influencing the decreases in albedo as their effect on making clouds brighter diminishes (e.g. Hodnebrog et al. (2024)), while the additional steady rise in ASR during the CERES period is also consistent with cloud and ice-albedo feedbacks to warming (Forster et al. (2021); Tselioudis et al. (2025); and Norris et al. (2016)) as well as declining global aerosol emissions (Quaas et al. (2022)).

8.4 Declining planetary albedo and recent record warmth

Page 91

MISLEADING

The issue then becomes the cause of the change in cloud cover. Two explanations have been posited for the declining cloud cover over the past decade: • Natural climate variability • Changes in low cloud cover associated with warming sea surface temperatures, implying an emerging positive feedback to climate change (Hansen and Karecha (2025))

Prof Richard Allan, professor of climate science, University of Reading

Two explanations for decreased global albedo are presented, but the decline in ocean aerosols is ignored and this has been identified as an important driver of decreased global albedo (e.g. Hodnebrog et al. (2024)). Combined with overemphasis of the abruptness of changes, this is potentially misleading since it overemphasises the role of natural variability.

8.4 Declining planetary albedo and recent record warmth

Page 92

MISLEADING

It is not easy to justify a new positive low cloud feedback that began emerging in 2015 since there is no obvious feedback trigger starting at that time.

Dr Helge F. Goessling, climate physicist and group leader, Alfred Wegener Institute

I think this is an example of a "straw man argument", because it's clear that there would not be a trigger starting exactly at some point. Rather, a forced signal (like a positive cloud feedback) would be superimposed by natural variations, and at some point, depending on signal-to-noise ratio (and possible other forcings) and how the associated forcing grows, the forced signal can emerge from the noise. An associated timeseries may just look like something kicked in at a specific time.

8.4 Declining planetary albedo and recent record warmth

Page 92

MISLEADING

However, there are numerous natural climate signals during this period that are associated with atmospheric circulation changes that can influence the distribution of clouds: • The 2014-16 was one of the strongest El Niño events on record. • A cold anomaly beginning in 2015 in the subpolar gyre of the North Atlantic reflects a shift in the ocean circulation pattern associated with decadal variability in the Atlantic (Frajka-Williams et al. (2017); Arthun et al. (2021)). • The Pacific Decadal Oscillation positive index peaked in 2016, then declined and has been in negative territory since late 2019. • Eruption of the submarine Hunga-Tonga volcano in 2022.

Dr Helge F. Goessling, climate physicist and group leader, Alfred Wegener Institute

When it comes to natural variability, they are listing quite comprehensively which aspects of natural variations could – in principle – have had an impact on planetary albedo, in part also overemphasising some aspects that rather clearly can not have had a major impact on the longer-term decline, such as ENSO (as we also investigated in our paper). Also their interpretation of results for the Hunga Tonga eruption and its possible contribution to the recent warming surge seems not to be a balanced representation of the recent literature about it, which does not suggest a major contribution. Also, they provide their list of natural variability aspects right after the down-playing statement about the possible low-cloud feedback mentioned above, saying: “However, there are numerous natural climate signals during this period that are associated with atmospheric circulation changes that can influence the distribution of clouds.” This shows quite clearly that they want to emphasise the natural variability over the possible low-cloud feedback.

Quote given to Carbon Brief

8.4 Declining planetary albedo and recent record warmth

Page 92

MISLEADING

It is not easy to justify a new positive low cloud feedback that began emerging in 2015 since there is no obvious feedback trigger starting at that time.

Prof Richard Allan, professor of climate science, University of Reading

A change in the SST pattern has been linked to a decline in low-altitude cloud over some stratocumulus regions (Andrews et al. (2022) and Loeb et al. (2020)) and it is misleading to paint these changes as requiring new feedbacks.

Quote given to Carbon Brief

8.4 Declining planetary albedo and recent record warmth

Page 92

MISLEADING

A change of 1-2% in global cloud cover has a greater radiative impact on the climate than the direct radiative effect of doubling CO₂.

Prof Richard Allan, professor of climate science, University of Reading

Short-term interannual fluctuations are unfairly compared with long-term radiative forcing. Also, a decrease in global albedo is an expected consequence of global warming as feedbacks cause ice to melt and some clouds to diminish (e.g. Forster et al. (2021)). This signal in shortwave radiation is seen to a greater extent than in the longwave since decreases in outgoing longwave due to rising greenhouse gases being offset by the increases in outgoing longwave from the resulting higher temperatures that are influenced by the greenhouse gases, but also declining aerosol and feedbacks that amplify the warming through ice melt and cloud responses to warming (e.g. Raghuraman et al. (2024)).

8.6 Extreme event attribution (EEA)

Page 96

FALSE

The existence of an outlier at the end of a data series poses the problem that estimates of the event probabilities will be biased whether the outlier is included or excluded (Barlow et al. (2020)). Methods to eliminate the bias have not yet been established.

Dr Ophélie Miralles, Prof Anthony C. Davison, research scientist, professor of mathematics, ETH Zurich, École Polytechnique Fédérale de Lausanne

The text suggests that the presence of the trigger event at the end can't be dealt with, whereas the argument in Barlow and in our paper is that it can be dealt with (if the selection event is known) with appropriate statistical methods specifically detailed in both papers.

8.6 Extreme event attribution (EEA)

Page 96

MISLEADING

Methods to eliminate the bias have not yet been established, leading some experts (e.g. Miralles and Davison (2023)) to argue that in settings in which a data series contains a single extreme event at the end, estimation of a return period for the extreme event will be so biased and uncertain that it should be avoided altogether.

Dr Ophélie Miralles, Prof Anthony C. Davison, research scientist, professor of mathematics, ETH Zurich, École Polytechnique Fédérale de Lausanne

The cited paper does argue that the estimated return period is highly variable and so one should avoid using it, but also states that if it has to be used, one should clearly state its uncertainty. It does not imply that fast

weather attribution should not be performed at all.

8.6 Extreme event attribution (EEA)

Page 97

MISLEADING

Zeder et al. (2023) also concluded that the methods employed by Philip et al. (2022, the WWA analysis) tend to overstate the rarity of extreme heat waves, leading to a biased perception of the effect of climate change on the heatwave event: “The tendency to overestimate the return period of observed extreme heatwave events may fuel the impression that seemingly impossible heatwave extremes are currently clustering at an unprecedented rate.”

Prof Erich Fischer, lecturer at the department of environmental systems science, ETH Zurich

The quote taken from the paper Zeder et al. (2023) led by my (former) PhD student, Joel Zeder, is in itself correct, yet taken completely out of context. Our paper shows indeed that when using relatively short observational timeseries, return level estimates may be systematically underestimated and return periods may be overestimated, which affects the calculation of the risk ratio in attribution studies. We further concluded that the risk of extreme heatwaves could be underestimated in both past and present-day climate and recommend following an approach like Miralles and Davison (2023). This paper applied the recommended approach specifically to the 2021 Pacific north-west heatwave.

However, both Miralles and Davison (2023) and Zeder et al. (2023) show that while methodological choices affect the exact estimate of the risk ratio, all estimates show a strong role of long-term warming increasing the probability of the event.

Part III: Impacts on ecosystems and society

9.1 Econometric analyses

Page 104

FALSE

Bareille and Chakir (2023) assembled a large data base on farm sale prices in France for properties that sold twice between 1996 and 2019. They could replicate pessimistic results showing negative effects of warming on agricultural land values using conventional econometric modelling.

Dr Francois Bareille, researcher in economics, INRAE & University Paris-Saclay

Bareille and Chakir (2023) do reproduce the standard results obtained from “conventional econometric modelling” like the Ricardian approach proposed by Mendelsohn et al. (1994). However, these standard results in no way demonstrate “negative effects of warming on agricultural land values”. Rather, as illustrated in Figure 5 of their study, Bareille and Chakir (2023) closely mimic the outcomes of the Ricardian approach in similar contexts, which points to slightly positive impacts of climate change on farmland values. Such findings are consistent with the broader literature when applied to contexts with moderate climate conditions.

Nevertheless, as has been extensively discussed, these results are likely subject to bias arising from omitted variables.

9.1 Econometric analyses

Page 104

FALSE

But by taking advantage of the repeat sales data, which provides information on site-specific changes in land prices, they found the results reversed and implied that climate change will be very beneficial for French agriculture.

Dr Francois Bareille, researcher in economics, INRAE & University Paris-Saclay

Bareille and Chakir (2023) do not identify any negative impacts of climate change on land values; across all methodologies they employ, the evidence consistently points toward positive effects of recent climate trends. Quote given to Carbon Brief

9.1 Econometric analyses

Page 104

MISLEADING

But by taking advantage of the repeat sales data, which provides information on site-specific changes in land prices, they found the results reversed and implied that climate change will be very beneficial for French agriculture.

Dr Francois Bareille, researcher in economics, INRAE & University Paris-Saclay

These results are derived from recent climate trends over the period 1990-2020 in the context of French agriculture. While such moderate warming may generate short-term benefits for agriculture, more substantial – and as yet unobserved – warming is likely to result in losses. It is well established that higher temperatures induced by climate change can produce non-linear effects, with moderate warming potentially yielding gains, but more pronounced warming leading to detrimental impacts.

Quote given to Carbon Brief

9.1 Econometric analyses

Page 104

MISLEADING

But by taking advantage of the repeat sales data, which provides information on site-specific changes in land prices, they found the results reversed and implied that climate change will be very beneficial for French agriculture.

Dr Francois Bareille, researcher in economics, INRAE & University Paris-Saclay

While such a result may arise in contexts like France (where northern regions remain, for the time being, too cold to cultivate high-value crops), these findings are highly context-specific and cannot be generalised to other settings. This is particularly true for a large and heterogeneous country like the US, where both climatic and agricultural conditions differ substantially from those in France. Bareille and Chakir (2023) provide indirect evidence that the positive impacts of recent climate change on French agriculture identified with their approach are likely driven by vineyard expansion, a phenomenon highly specific to France and not transferable to the US context.

9.1 Econometric analyses

Page 104

MISLEADING

The authors concluded that, taking adaptation into account, a warming climate would yield positive benefits for French agriculture that were between two and 20 times larger than had previously been estimated. On average, with full adaptation, they concluded that climate changes under the medium RCP4.5 scenario could double the value of French farmland by 2100.

Dr Francois Bareille, researcher in economics, INRAE & University Paris-Saclay

These results are obtained using a novel method, the so-called repeat-Ricardian approach. In contrast to other studies cited in the report – such as Mendelsohn et al. (1994), Deschênes and Greenstone (2007), Schlenker and Roberts (2009) and Burke and Emerick (2016) – this approach has not yet been replicated in other contexts. Its findings should therefore be interpreted with caution. By comparison, dozens of replications and extensions of Deschênes and Greenstone (2007), Schlenker and Roberts (2009) and Burke and Emerick (2016) consistently document negative impacts of climate change on crop productivity in the US, but also worldwide.

9.1 Econometric analyses

Page 105

MISLEADING

A major deficiency of all these studies, however, is that they omit the role of CO₂ fertilisation. Climate change as it relates to this report is caused by GHG emissions, chiefly CO₂. The econometric analyses referenced above focus only on temperature and precipitation changes and do not take account of the beneficial growth effect of the additional CO₂ that drives them.

Dr Francois Bareille, researcher in economics, INRAE & University Paris-Saclay

All of these studies implicitly account for the effects of CO₂ fertilisation on agriculture insofar as local CO₂ concentrations are correlated with changes in temperature and precipitation. Moreover, Hultgren et al. (2025) show that the positive effects of CO₂ fertilisation only partially offset the negative impacts of anthropogenic climate change on crop yields arising from changes in temperature and precipitation.

9.2 Field and laboratory studies of CO₂ enrichment

Page 105

MISLEADING

One of the ways the effect of CO₂ on crop growth has been studied is through “free air enrichment experiments” or FACE plots, in which small sources of CO₂ are placed in fields surrounding plants and the growth response to elevated CO₂ under varying weather conditions are recorded. Ainsworth et al. (2020) summarises results from about 250 such studies. They found that elevation of CO₂ by 200ppm caused an average 18% increase in crop yield in C₃ plants. C₄ plants exhibited benefits mainly under drought conditions.

Prof Steve Long, Ikenberry Endowed University Chair, University of Illinois

While this report is correct in saying that, in isolation, our research has shown that an increase in CO₂ does (on average for C₃ crops) results in increased yields and decreased quality, and that it can increase water use efficiency. But when account is taken of the accompanying changes in tropospheric ozone, temperature, atmospheric water vapor pressure deficit and extreme drought, heat and flooding events then the overall effect of GHG driven climate and atmospheric change is strongly negative.

Quote given to Carbon Brief

9.3 Crop modeling meta-analyses

Page 107

MISLEADING

McKittrick (2025) re-examined the Moore et al. database and found that, while it claimed to cover 1,722 studies, only half the entries (N=862) had complete records, so that the sample available for regression analysis was much smaller than both studies indicated. McKittrick noted that the records most commonly missing were the changes in ambient CO₂ and found that in many cases these could be recovered from the underlying studies or the original climate scenario tables, thereby increasing the usable sample size by 40%. The crop yield projections incorporating the newly available data changed considerably. As shown in Figure 9.2, whereas the partial data set implied warming would decrease yield (blue lines), the complete data set implied constant or increase global yields, even out to 5C warming (green lines).

Dr Delphine Deryng, lead author, IPCC AR6 WG2

Regression analysis of historical climate impacts on crop yield do not capture the impact of non-linear processes, such as effects of extreme heat stress occurring at crop anthesis. Hence the conclusion based on a single approach is misleading (Moore et al. (2017) and McKittrick (2025)). The IPCC assessed a range of peer-reviewed publications based on regression analysis and process- based models, also including the CO2 fertilisation effects (for example, see AR6 WG2, chapter 14, p1,956, for synthesis on US agriculture).

9.4 CO2 fertilization and nutrient loss

Page 107

MISLEADING

Evidence has shown that CO2-induced biomass gains are sometimes accompanied by reductions in the concentrations of protein and other key nutrients such as iron and zinc (Ebi et al. 2021)."

Prof Kristie Ebi, professor of global health, and Dr Becca Neumann, associate professor of civil and environmental engineering

All plants absorb carbon dioxide from the atmosphere, using photosynthetic pathways to break down that carbon dioxide into carbon and oxygen, and then using the carbon to grow. Eighty-five percent of plants use a photosynthetic pathway that, based on biochemical characteristics, is termed C3; these C3 plants include important crops such as wheat, rice, barley, oats, rye, soybean and potatoes. Field experiments with wheat and rice under a doubling of CO2 from pre-industrial concentrations demonstrate that protein declines by about 10%, B-vitamins by as much as 30% and micronutrients by about 5% (see Ebi et al. (2021) and associated references). Wheat and rice each provide about 20% of calories consumed worldwide, with wide regional variability (Awika (2011) and Shiferaw et al. (2013)). Corn, sorghum and millet use a different photosynthetic pathway (C4) and are not expected to experience declines in nutrient density with higher CO2 concentrations. The DoE CWG report conflates these two photosynthetic pathways into "sometimes" without being clear that declines in nutrient density are consistently seen under elevated CO2 for C3 crops (Loladze (2002) and (2014); Loladze et al. (2019); Myers et al. (2014); Taub et al. (2008); J. Wang et al. (2019) and (2020); and Zhu et al. (2018)), which are widely consumed in the US.

The DoE CWG report also ignores a key fact raised in Ebi et al. (2021) that elevated CO2 and elevated temperature can increase toxins such as arsenic and cadmium in crops (Dhar et al. (2020); Farhat et al. (2021) and (2023); Guo et al. (2011); Muehe et al. (2019); J. Wang et al. (2019); Y. Wang et al. (2023); and Yuan et al. (2021)), not just dilute nutrients. Ingestion of toxins in food results in illness, shortened life span, reduced quality of life and death (Gibb et al. (2019)).

9.4 CO2 fertilization and nutrient loss

Page 107

MISLEADING

Some experiments have shown that the rising temperatures expected to accompany higher CO2 levels will offset this loss (Köhler et al. (2019)) although the evidence for this is mixed, as is the

evidence that nutrient dilution observed to date is entirely attributable to higher CO₂ (Ziska (2022)).

Prof Kristie Ebi, professor of global health, and Dr Becca Neumann, associate professor of civil and environmental engineering

Some experiments have shown that rising temperatures expected to accompany higher CO₂ levels can offset nutritional losses (Köhler et al. (2019) and, while the DoE CWG report acknowledges that evidence for this temperature compensation is mixed, it fails to cite studies that found partial or no compensation in nutritional density when elevated CO₂ was crossed with elevated temperature (e.g., Jayawardena et al. (2021); J. Wang et al. (2019); Wei et al. (2021); and Ziska et al. (1997)). On the flip side of crop nutritional quality, increased temperatures are expected to increase toxin levels in crops. Wang et al. (2020) found that while warmer temperatures moderately mitigated the loss of nutrients associated with elevated CO₂, the warmer temperatures simultaneously increased manganese, molybdenum, chromium, nickel, cadmium and lead concentrations in rice and wheat. A study investigating arsenic contamination of rice found that grain arsenic concentrations were more elevated when elevated CO₂ was combined with elevated temperature than when either elevated CO₂ or elevated temperature operated alone (Muehe et al. (2019)).

The second half of the statement above (i.e., "... as is the evidence that nutrient dilution observed to date is entirely attributable to higher CO₂") draws an incorrect conclusion from Ziska (2022). Ziska (2022) presents a figure (Figure 1) that shows newer breeding lines of spring wheat have less percent protein, but that all the breeding lines have experienced declines in percent protein over the 20th century. Thus, Ziska (2022) acknowledges that breeding can change nutritional density but ultimately concludes that "[CO₂] is directly affecting protein concentration separate from breeding history".

Quote given to Carbon Brief

9.4 CO₂ fertilization and nutrient loss

Page 107

MISLEADING

If nutrient dilution does occur under rising CO₂ levels, there are several adaptive strategies that could be pursued. First, selective breeding to raise micronutrient content is already established (Saltzman et al. (2017)) and has proven to be a cost-effective agronomic strategy (Ebi et al. (2021)).

Prof Kristie Ebi, professor of global health, and Dr Becca Neumann, associate professor of civil and environmental engineering

Biofortification via selective breeding has been used successfully to raise the zinc, iron and vitamin A content of crops, per Saltzman et al. (2017). However, this approach is not a "proven" agronomic strategy, cost-effective or otherwise, for addressing simultaneous nutrient dilution by elevated CO₂. Ebi et al. (2021) specifically stated: "An additional challenge for biofortification is the tendency of rising CO₂ concentrations to diminish the concentrations of multiple nutrients concomitantly (Loladze (2014a) and (2014b)) in contrast to biofortification that targets only one or a few selected nutrients." Further, biofortification cannot address the issue of increased toxin levels in crops associated with elevated CO₂ and CO₂-induced warming.

References

Page 108

FALSE

Deryng, D., Elliott, J., Folberth, C. et al. (2021) Regional disparities in the beneficial effects of rising CO2 concentrations on crop water productivity. Nature Climate Change 6, 786–790 (2016). <https://doi.org/10.1038/nclimate2995>

Dr Delphine Deryng, lead author, IPCC AR6 WG2

The date of the citation is incorrect, and I didn't find reference to this paper in the text of the chapter
Quote given to Carbon Brief

9.4 CO2 fertilization and nutrient loss

Page 108

MISLEADING

Optimal strategies will be location-specific because they vary by crop, climate and soil type (Ebi et al. (2021)).

Prof Kristie Ebi, professor of global health, and Dr Becca Neumann, associate professor of civil and environmental engineering

Developing new cultivars requires significant investments and generally take years (see CGIAR programmes). Such programmes will not be developed locally, nor will the investment make sense if the developed cultivar only applies to a specific location.

9.4 CO2 fertilization and nutrient loss

Page 108

MISLEADING

Second, fortification of food products with micronutrients is already routine. Folic acid (a B vitamin) is added to flour and many other foods; iodine is added to table salt, most commercial breakfast cereals are fortified with iron and numerous vitamins, etc. Third, dietary supplements in the form of multivitamin tablets are inexpensive, widely-available and routinely consumed.

Prof Kristie Ebi, professor of global health, and Dr Becca Neumann, associate professor of civil and environmental engineering

Fortification and dietary supplements do not currently alleviate nutrient deficiencies; therefore, it is unlikely that such approaches will alleviate nutrient deficiencies in the future, particularly if they are exacerbated by lower crop nutrient density. For example, 30% of women and girls worldwide (15-49 years) currently have iron-deficiency anemia (World Health Organization, 2025), including nearly 40% of women and girls (12-21 years) in the US (Weyand et al. (2023)). These deficiencies exist despite decades of dietary supplement

availability (Macdougall (2017)). The DoE CWG report ignores that high CO₂ concentrations affect a wide range of macro and micronutrients beyond iron and zinc, such as lithium (for mental health), magnesium (for muscle and nerve function, blood pressure regulation, bone health and energy production) and others (Loladze (2014)). Dietary supplements do not address these critical contributions to hidden hunger (Wallace et al. (2014)). US government guidelines emphasise that supplements are not an adequate substitute for a nutrient dense diet (US Department of Agriculture and US Department of Health and Human Services (2010)). Further, fortification of food or use of supplements will not address the health risk posed by increased toxin concentrations in grain associated with elevated CO₂ and CO₂-induced warming.

9.4 CO₂ fertilization and nutrient loss

Page 108

MISLEADING

One concern about reliance on adaptive strategies is whether they are feasible in low-income countries. Micronutrient deficiency is already a problem in the developing world and dietary supplements have proven to be an effective low- cost response (Ebi et al. (2021)).

Prof Kristie Ebi, professor of global health, and Dr Becca Neumann, associate professor of civil and environmental engineering

As noted in the previous comment, micronutrient deficiency is a health problem in developing and developed countries; dietary supplements have not solved the problem. Micronutrient deficiency is expected to increase with elevated CO₂ (Beach et al. (2019); Smith and Myers (2019); Weyant et al. (2018); and Zhu et al. (2018)). As supplements have been unable to fully address the current deficiencies in micronutrients, it is unlikely they will successfully ameliorate a future increased health burden caused by nutrient dilution in crops. In addition, as noted in the previous comment, supplements will not address the health issues posed by increased toxin concentrations in grain expected with elevated CO₂ and CO₂-induced warming.

9.4 CO₂ fertilization and nutrient loss

Page 108

MISLEADING

It should also be noted the IPCC emission scenarios that generate high levels of warming also involve strong income growth. The SSP scenarios assume that, compared to 2005 levels, global per capita income will double by 2100 in the lowest growth case (SSP3), and in the highest emission case (SSP5) global per- capita income will grow nearly 16-fold. In that scenario even the poorest regions (Africa and the Middle East) end up with a per capita income of about US\$126,000, 70% higher than current US per capita income (about US\$75,000). Consequently the same scenarios in which CO₂ levels increase the most are also those in which global poverty is largely eliminated, in which case all countries would be able to afford dietary supplements as necessary to address micronutrient deficiencies, if they arise and cannot be addressed using on- farm agricultural strategies.

Prof Kristie Ebi, professor of global health, and Dr Becca Neumann, associate professor of civil and environmental engineering

The US is one of the wealthier countries in the world, yet many US citizens suffer from micronutrient deficiencies. Wallace et al. (2014) used data from the National Health and Nutrition Examination Survey (2007-10) to determine that despite the fact that 51% of Americans consume multivitamin/mineral supplements with greater than nine micronutrients, many fail to meet the estimated average requirement for vitamin A (35%), vitamin C (31%), vitamin D (74%), vitamin E (67%), vitamin K (77%), calcium (39%), magnesium (46%), potassium (100%) and choline (92%). Bird et al. (2017) concluded that “nearly one-third of the US population is at risk of deficiency in at least one vitamin, or has anemia”.

Growth and development of children and lifespan health depends on adequate intake of micronutrients. Decreasing the nutrient density of diets through continued emissions of CO₂ will exacerbate the situation, even with any associated income growth. Ingestion of toxins in food is a global problem that affects the health of millions of people, including those living in wealthy countries (Consumer Reports (2012) and (2014); and Gibb et al. (2019)). A growth in income will not offset the health risk posed by contaminated food. It is expected that this health risk will grow as elevated CO₂ and CO₂-induced warming increase the toxin content of crops (Dhar et al. (2020); Farhat et al. (2021) and (2023); Guo et al. (2011); Muehe et al. (2019); J. Wang et al. (2019); Y. Wang et al. (2023); and Yuan et al. (2021)).

9.4 CO₂ fertilization and nutrient loss

Page 108

MISLEADING

In summary, there is abundant evidence going back decades that rising CO₂ levels benefit plants, including agricultural crops, and that CO₂-induced warming will be a net benefit to US agriculture. To the extent nutrient dilution occurs there are mitigating strategies available that will need to be researched and adapted to local conditions.

Prof Kristie Ebi, professor of global health, and Dr Becca Neumann, associate professor of civil and environmental engineering

There is abundant evidence that under ideal conditions (i.e., adequate nutrients and water and optimal temperatures), crop productivity increases with rising CO₂ levels (e.g., Ainsworth & Long (2020)). These increases diminish or disappear when conditions are non-ideal (i.e., nutrients are limited, water and temperatures are sub-optimal). As CO₂ concentrations increase, ambient temperatures will continue warming and weather patterns will shift, altering water and nutrient availability. It is not clear that boosts in productivity generated by elevated CO₂ will compensate for the damage to plant productivity caused by these other stressors. In many parts of the world, even with adaptation, crop yields are expected to decline (Hultgren et al. (2025)).

Further, discussed in the comments above, elevated CO₂ is associated with declining nutrient density in crops. Therefore, it is disingenuous to state that there is “abundant evidence going back decades that rising CO₂ levels benefit plants”. This statement cherry-picks the productivity boost to plants associated with rising CO₂ levels while ignoring the negative human health outcomes that will co-occur. The scientific consensus is that CO₂-induced warming will be harmful to US agriculture, leading to yield declines (Hu et al. (2024); Hultgren et al. (2025); Lobell et al. (2011); Lobell and Field (2007); and Zhao et al. (2017)). Physiological studies of crops show there is an optimal temperature at which yields maximise. When temperatures are below or above this optimal point, yields decline.

Further, as outlined in the comments to Section 9.4 above, CO₂-induced warming is associated with increased toxin levels in crops. It is factually inaccurate to state that “CO₂-induced warming will be a net benefit to US

agriculture”. There are strategies, such as biofortification and supplementation, that can be employed to help mitigate nutrient dilution in crops, as discussed in Ebi et al. (2020). However, as outlined in the comments above, these approaches currently do not address nutrient deficiencies and therefore it is unrealistic to expect that they will be able to address future nutrient deficiencies exacerbated by rising CO2 levels and crop nutrient density. Further, these strategies will not solve the problem of increased concentrations of toxins in crops associated with increased CO2 and/or CO2-induced warming.

10.3 Mortality from temperature extremes

Pages 122-124

MISLEADING

Section 10.3.1

Dr Antonio Gasparrini, biostatistician and epidemiologist, London School of Hygiene & Tropical Medicine

In relation to my area of research, the report cites two articles (Gasparrini (2015) and Zhao (2021)) in support of the statement that cold-related mortality far exceeds heat-related mortality in most of the regions. While true, this says little about the impact of climate change on temperature-related deaths. In fact, the focus should be on the respective (and opposite) change in the heat and cold contributions, not their absolute values. In this respect, there is some evidence that the expected reduction in cold-related mortality will not offset the increase in heat-related mortality, in particular under more extreme climate change scenarios (Gasparrini (2017) and Masselot (2025)). More importantly, the level of adaptation to heat required to offset such a positive net effect should be very high, in the order of 90% reduction (Masselot (2025)).

Quote given to Carbon Brief

11 Climate change, the economy, and the social cost of carbon

Page 116

FALSE

An influential study in 2012 suggested that global warming would harm growth in poor countries, but the finding has subsequently been found not to be robust. Studies that take full account of modelling uncertainties either find no evidence of a negative effect on global growth from CO2 emissions or find poor countries as likely to benefit as rich countries.

Prof Richard Tol, professor at the department of economics, University of Sussex

“The second sentence is wrong. The authors refer to “studies”, but without references. Tol (2024) finds that the then-available studies jointly point to a negative impact of climate change on global economic growth. My less systematic reading of the literature since has not led me to change my mind. Their conclusion that ‘poor countries’ are ‘likely to benefit’ is again not backed up with references. Tol (2024), the only reference in the paragraph, concludes the opposite.”

11.1 Climate change and economic growth

MISLEADING

Nor have past extreme weather events had a significant effect on US banks' performance (Blickle et al. (2021)); warming has even been shown to be beneficial for the finance and insurance sector (Mohaddes et al. (2023)).

Dr Kamiar Mohaddes, deputy director of the Cambridge executive MBA programme,
University of Cambridge

“The way our findings have been presented is misleading... Investigating the long-term macroeconomic effects of climate change across 48 US states, we provide evidence for the damage that climate change causes in the US using various economic indicators at the state level: growth rates of Gross State Product (GSP), GSP per capita (income), labour productivity and employment as well as output growth in 10 economic sectors (e.g. agriculture, manufacturing, services, retail and wholesale trade). Just to be clear, (1) these are not ‘small negative effects’ and (2) we do indeed show that climate change has negative effects on income in the US. We show that while hashtag#weather shocks have level effects (or temporary growth impacts), climate change – by shifting the long-term average and variability of weather – impacts the US economy’s ability to grow in the long term! We study economic activity in all sectors of the US economy –agriculture, forestry & fisheries; mining, construction, manufacturing, transport, communications and public utilities, wholesale trade, retail trade, financial services & property, services and government –and find that the impact of climate change on sectoral output growth is broad based – each of the 10 sectors considered is affected by at least one of the four climate variables.”

11.2 Models of the social cost of carbon

Page 121

MISLEADING

Economists use IAMs to compute the SCC. Two of the best-known are the Climate Framework for Uncertainty, Negotiation and Distribution (“FUND”, Tol 1997) and Nordhaus’ DICE. EPA (2023) introduced new ones for its recent work. IAMs embed a “damage function” or set of functions relating ambient temperature to local economic conditions. The assumptions embedded in the damage function will largely determine the resulting SCC. IAMs also assume a long-term discount rate or, as in DICE, compute the optimal internal discount rate as part of the solution.

Prof Richard Tol, professor at the department of economics, University of Sussex

“The literature is vast. I counted 446 papers with estimates. There are numerous commentaries; and two handfuls of meta-analyses (e.g. Tol (2023) and Moore et al. (2024)). Instead, the authors wrote their own review, which omits the most influential papers and misses key insights. Cherry-picking may be a better term than review.”

11.2 Models of the social cost of carbon

Page 123

FALSE

Tol (2017) estimates that the private benefit of carbon is large relative to the social cost.

Prof Richard Tol, professor at the department of economics, University of Sussex

“This paper was never published in a peer-reviewed journal and is therefore not admissible by the rules of the US government. The paper was peer-reviewed and rejected, because my private benefit [of carbon] is an average, whereas the social cost is a marginal. The two cannot be compared (unless you make a ridiculous assumption about linearity). I still hope to fix the paper one day. As it stands, however, the comparison is wrong.”

Quote from external source

ny No. 07222041

From: Ross McKittrick <ross.mckittrick@gmail.com>
Sent: Thursday, May 15, 2025 10:20 AM
To: Judith Curry
Cc: Steven Koonin; John Christy; Roy W. Spencer; Travis Fisher
Subject: Re: Part I

Leaving it out opens us up to the charge of ignoring what seems to be adverse evidence. My read of the attachment isGrok3 didn't do a very good job --took the Guardian (!) at face value but left out AIMS altogether. We can talk about the evidence of long term decline but also cite the AIMS report showing a large recent rebound. The AIMS data is a high credibility government source. We don't need to make any overly triumphant claims just present the numbers and point out that it's another case of short records, complicated dynamics and media ignoring what appears to be good recent news.

On Thu, May 15, 2025 at 10:13 AM Judith Curry <curry.judith@cfanclimate.com> wrote:
I did a Grok3 search on coral reef health (attached). If we are going to discuss coral reefs, we have to do a lot more than reference Peter Ridd. I suggest we leave this out.

On Thu, May 15, 2025 at 5:47 AM Steven Koonin <steven.koonin@gmail.com> wrote:
Climate-driven loss of coral is certainly out there in the public consciousness. So we need to say We need to say something somewhere about it lest we be criticized for avoiding discussion of it - ie cherry picking the impacts we cover.

Steven E. Koonin

On May 15, 2025, at 05:29, Judith Curry <curry.judith@cfanclimate.com> wrote:

Another thought I had last night (instead of sleeping)

I suggest combining chapters 2 and 3 into one chapter:

- 2. Direct environmental impacts of CO2
 - 2.1 Land - global greening
 - 2.2 Ocean - alkalinity

In the alkalinity chapter, I think we should remove discussion of coral reefs, since that is mostly a temperature issue

On Wed, May 14, 2025 at 4:18 PM Steven Koonin <steven.koonin@gmail.com> wrote:

That works. Thanks.

SEK

From: Ross McKittrick <ross.mckittrick@gmail.com>
Sent: Wednesday, May 14, 2025 7:17 PM
To: Steven Koonin <steven.koonin@gmail.com>
Cc: Judith Curry <curry.judith@cfanclimate.com>; John Christy <climatemanager60@gmail.com>; Roy W. Spencer <roywspencer@hotmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>
Subject: Re: New folder: 01.Report Draft

This should get you in

https://www.dropbox.com/scl/fo/wahx6lpwzu33m5vyrr8x/ANTU1qAQJ-zXCFzP_gsJcOs?rlkey=l1z3qj9v46elt5f4ywwxq7p8c&dl=0

This is for the parent folder. Let me know if it doesn't work.

On Wed, May 14, 2025 at 6:41 PM Steven Koonin <steven.koonin@gmail.com> wrote:

Can you please send a link to the new folder?

Thanks.
Steven E. Koonin

> On May 14, 2025, at 15:27, Ross McKittrick <ross.mckittrick@gmail.com> wrote:
>
>
> Following our meeting today I created a new folder containing clean copies (all past tracked changes accepted) of all chapters.
> There are some marginal queries and in-line comments remaining to be resolved, missing Figure captions in a couple of places etc. If you are able to supply the missing info go ahead and do so. We will soon need to sign off on final text versions so please read through them.
> I propose that these should be the versions we talk through next week.
>
> Question: should there be a single list of references at the very end or should each chapter have its own reference list? Initially I thought the former but now I lean towards the latter.
>

From: Judith Curry <curry.judith@cfanclimate.com>
Sent: Thursday, May 15, 2025 10:34 AM
To: Ross McKittrick
Cc: Steven Koonin; John Christy; Roy W. Spencer; Travis Fisher
Subject: Re: Part I

I prefer to leave it out, rather than write something that opens us up to criticism (what we currently have would open us up to much criticism). If we do include this, we need to do much more than what we currently have, citing AR6, more recent references etc.

On Thu, May 15, 2025 at 7:20 AM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

Leaving it out opens us up to the charge of ignoring what seems to be adverse evidence. My read of the attachment is Grok3 didn't do a very good job --took the Guardian (!) at face value but left out AIMS altogether. We can talk about the evidence of long term decline but also cite the AIMS report showing a large recent rebound. The AIMS data is a high credibility government source. We don't need to make any overly triumphant claims just present the numbers and point out that it's another case of short records, complicated dynamics and media ignoring what appears to be good recent news.

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From: Travis Fisher <travis.scott.fisher@gmail.com>
Sent: Thursday, May 15, 2025 10:41 AM
To: Judith Curry
Cc: Ross McKittrick; Steven Koonin; John Christy; Roy W. Spencer
Subject: Re: Part I

Is this an area where you could assign some research work to me and Josh? For my part, I don't mind the extra effort, and I think retaining some negative trends (even if the systems are complex or not well understood) will cut against accusations of bias.

On Thu, May 15, 2025 at 10:34 AM Judith Curry <curry.judith@cfanclimate.com> wrote:

I prefer to leave it out, rather than write something that opens us up to criticism (what we currently have would open us up to much criticism). If we do include this, we need to do much more than what we currently have, citing AR6, more recent references etc.

On Thu, May 15, 2025 at 7:20 AM Ross McKittrick <ross.mckittrick@gmail.com> wrote:

Leaving it out opens us up to the charge of ignoring what seems to be adverse evidence. My read of the attachment is Grok3 didn't do a very good job --took the Guardian (!) at face value but left out AIMS altogether. We can talk about the evidence of long term decline but also cite the AIMS report showing a large recent rebound. The AIMS data is a high credibility government source. We don't need to make any overly triumphant claims just present the numbers and point out that it's another case of short records, complicated dynamics and media ignoring what appears to be good recent news.

On Thu, May 15, 2025 at 10:13 AM Judith Curry <curry.judith@cfanclimate.com> wrote:

I did a Grok3 search on coral reef health (attached). If we are going to discuss coral reefs, we have to do a lot more than reference Peter Ridd. I suggest we leave this out.

On Thu, May 15, 2025 at 5:47 AM Steven Koonin <steven.koonin@gmail.com> wrote:

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On May 15, 2025, at 05:29, Judith Curry <curry.judith@cfanclimate.com> wrote:

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In the alkalinity chapter, I think we should remove discussion of coral reefs, since that is mostly a temperature issue

On Wed, May 14, 2025 at 4:18 PM Steven Koonin <steven.koonin@gmail.com> wrote:

That works. Thanks.

SEK

From: Ross McKittrick <ross.mckittrick@gmail.com>
Sent: Wednesday, May 14, 2025 7:17 PM
To: Steven Koonin <steven.koonin@gmail.com>
Cc: Judith Curry <curry.judith@cfanclimate.com>; John Christy <climateman60@gmail.com>; Roy W. Spencer <roywspencer@hotmail.com>; Travis Fisher <travis.scott.fisher@gmail.com>
Subject: Re: New folder: 01.Report Draft

This should get you in

https://www.dropbox.com/scl/fo/wahx6lpwzu33m5vyrr8x/ANTU1qAQJ-zXCFzP_gsJcOs?rlkey=l1z3qj9v46e1t5f4ywwxq7p8c&dl=0

This is for the parent folder. Let me know if it doesn't work.

On Wed, May 14, 2025 at 6:41 PM Steven Koonin <steven.koonin@gmail.com> wrote:

Can you please send a link to the new folder?

Thanks.
Steven E. Koonin

> On May 14, 2025, at 15:27, Ross McKittrick <ross.mckittrick@gmail.com> wrote:
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From: Ross McKittrick <ross.mckitrick@gmail.com>
Sent: Thursday, May 15, 2025 3:29 PM
To: Steven Koonin
Cc: Judith Curry; John Christy; Roy W. Spencer; Travis Fisher
Subject: Re: Part I

I did the merger and renumbered the sections and figures in ch's 2 and 3. In the 01.Report Draft folder the chapters now go 1, 2, 4, 5,... so perhaps someone from the DoE Department of Report Chapter Renumbering could go through and adjust Ch4 to Ch3, 5 to 4, etc., taking care to renumber the figures and the references in each chapter to other chapters as necessary.

On Thu, May 15, 2025 at 3:09 PM Steven Koonin <steven.koonin@gmail.com> wrote:

Yes, we should combine as Judy suggests.

SEK

PS There is already a separate thread on the coral issue.

From: Judith Curry <curry.judith@cfanclimate.com>
Sent: Thursday, May 15, 2025 8:30 AM
To: Steven Koonin <steven.koonin@gmail.com>
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From: Ross McKittrick <ross.mckitrick@gmail.com>
Sent: Thursday, May 15, 2025 5:53 PM
To: Travis Fisher
Cc: Steven Koonin; Judith Curry; John Christy; Roy W. Spencer
Subject: Re: Part I

This link should give you edit access to the whole folder. The files you want are in 01.Report Draft

https://www.dropbox.com/scl/fo/wahx6lpwzu33m5vyrr8x/ANTU1qAQJ-zXCFzP_gsJcOs?rlkey=fe667xxscc7wk2dlstcwyywg4&st=qdj1orfv&dl=0

On Thu, May 15, 2025 at 5:41 PM Travis Fisher <travis.scott.fisher@gmail.com> wrote:
I know someone in that department! Do I need any additional authorities / rights in Dropbox to edit the documents directly?

On Thu, May 15, 2025 at 3:29 PM Ross McKittrick <ross.mckitrick@gmail.com> wrote:
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Sent: 5/15/2025 2:12:50 PM
To: Steven Koonin [steven.koonin@gmail.com]
CC: Ross McKittrick [ross.mckittrick@gmail.com]; John Christy [climatemanager60@gmail.com]; Roy W. Spencer [roywspencer@hotmail.com]; Travis Fisher [travis.scott.fisher@gmail.com]
Subject: Re: Part I
Attachments: (17) Grok_X.pdf

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Profile

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Post

Deep Search

real estate

Explaining recent updates

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Completed

Completed

Key Points

- Research suggests coral reefs are declining globally, with over 50% lost since 1957.
- The evidence leans toward climate change as the main cause, causing bleaching and acidification.
- It seems likely local factors like overfishing and pollution also impact reef health significantly.

Overview

Coral reefs are vital ecosystems facing serious challenges. Studies show they are declining, with major impacts from climate change, including warmer oceans and acidification. Local issues like overfishing and pollution add to the stress. Recent events, like the 2023-2024 bleaching, have worsened the situation, affecting over 80% of reefs.

Detailed Findings

- Decline Status:** Research indicates a significant global decline, with a 50% loss in coverage since 1957 and 80% of coral species at risk of extinction by 2034.
- Climate Impact:** Rising ocean temperatures cause bleaching, where corals expel algae, risking death. Acidification from CO2 reduces calcium for coral skeletons, hindering growth.
- Local Factors:** Overfishing disrupts ecosystem balance, pollution degrades water quality, and coastal development adds physical damage, all reducing reef resilience.

For more details, see reports from EPA, UNEP, and NOAA.

Comprehensive Analysis of Coral Reef Health

Coral reefs, often referred to as the "rainforests of the sea," are critical ecosystems supporting a quarter of all marine species and providing essential services like coastal protection and fisheries. However, recent scientific assessments and reports, such as May 15, 2025, paint a concerning picture of their health, with evidence pointing to a global decline driven by both global and local factors. This analysis delves into the current status, causes of decline, and recent developments, drawing from authoritative sources like the Environmental Protection Agency (EPA), United Nations Environment Programme (UNEP), NASA, and the International Union for Conservation of Nature (IUCN).

Current Status of Coral Reefs

Research suggests that coral reefs are experiencing a significant decline. A study published by the Natural History Museum in 2021 found that coral reef coverage has fallen by over 50% since 1957, with associated biodiversity declining by 82% and fish abundance dropping by 50% in the Pacific Islands. The IUCN Red List update from November 2024 further highlighted the severity, noting that 84% of reef-building coral species are now at risk of extinction, up from one-third in 2008. The IUCN Blue List also underscores the urgency, with recent events amplifying the crisis.

A Guardian article from April 2025 reported that more than 90% of the world's coral reefs were hit by bleaching during the worst global event on record, spanning 2023 to 2024, with surveys indicating widespread coral mortality. The Global Coral Reef Monitoring Network (GCRMN) is compiling a 2025 status report, but preliminary data suggest the impact is profound, with recovery uncertain given ongoing stressors.

Regionally, the Great Barrier Reef, one of the largest reef systems, faces compounded pressures. The 2024 Outlook Report noted some ecosystem improvements, like seagrass meadows, due to management efforts, but climate-driven threats like warming oceans and cyclones continue to challenge resilience. Despite record growth in some areas post-bleaching, as noted in a 2023 WHC article, the overall outlook remains dire.

Causes of Variations in Coral Reef Health

The decline in coral reef health is driven by a complex interplay of global and local factors, each contributing to the stress on these ecosystems. Below is a detailed breakdown, organized by category, with supporting evidence from recent studies and reports.

Climate Change: The Dominant Global Threat

Climate change impacts as the primary driver, with ocean warming and acidification at the forefront. Rising sea temperatures cause coral bleaching, a process where corals expel their symbiotic algae (zooxanthellae), their primary food source, leading to starvation and potential death if conditions persist. The UNEP notes that mass bleaching events are predicted to increase in frequency and intensity as temperatures rise, with projections suggesting a 70-90% decline in live coral by 2050 at 1.5°C warming, and nearly 90% at 2°C. The planet has already warmed by 1.1°C since the 19th century, exacerbating the issue.

Ocean acidification, resulting from increased CO2 absorption, reduces the availability of calcium carbonate, essential for coral skeleton formation. The Natural History Museum explains that this process makes seawater more acidic, dissolving coral structures and reducing their ability to rebuild, with some reefs already beginning to dissolve. Natural History Museum, NASA's research, using satellite data, confirms that sea surface temperature and water quality changes are closely linked to coral health declines.

Local Factors: Adding Pressure to Vulnerable Systems

Local human activities significantly contribute to coral reef decline, often compounding the effects of climate change. These factors include:

- Overfishing:** Overfishing disrupts the ecological balance, reducing fish populations that control algae growth. The Natural History Museum study found that catches of coral reef fishes peaked in 2002 and have declined since, despite increased fishing effort, affecting 6 million people dependent on these fisheries. Natural History Museum. This loss impacts diets and livelihoods, particularly in tropical and small-island developing states.
- Pollution:** Pollution, including chemical runoff, fertilizers, and toxins, degrades water quality, stressing corals and making them more susceptible to bleaching. The EPA highlights that most coral reefs occur in shallow waters near shore, making them vulnerable to land-based pollution. EPA. Recent initiatives, like the Trash-Free Waters program in Puerto Rico, aim to reduce wastewater loading by 2025, but challenges remain.
- Unsustainable Coastal Development:** Activities like dredging and construction increase sedimentation, blocking sunlight and smothering corals. The UNEP notes that unsustainable coastal development adds local pressures, reducing reef resilience. UNEP. Physical damage from ships and divers, as mentioned in NASA's analysis, also plays a role.
- Disease:** Climate change and stressors like pollution make corals more susceptible to infectious diseases, which can spread rapidly. A ScienceDaily article from March 2025 highlighted the role of diseases, particularly in the Caribbean, in causing major declines in coral populations, affecting species like staghorn and elkhorn corals.

These local factors interact with global climate impacts, creating a feedback loop that reduces coral reefs' ability to recover. For instance, a reef weakened by bleaching may be more vulnerable to disease outbreaks or physical damage from storms.

Recent Developments and Future Outlook

Recent developments underscore the ongoing crisis. The 2023-2024 global bleaching event, driven by record ocean temperatures, has been particularly devastating, with the Guardian reporting widespread coral death following sweeps. ScienceDaily articles from early 2025 discuss challenges in coral restoration, noting that over a third of projects fail and may not scale effectively to mitigate losses. This suggests that while efforts like those by the Coral Reef Alliance are underway, the scale of the problem remains daunting.

Management initiatives, such as controlling crown-of-thorns starfish and enhancing tiger patrols on the Great Barrier Reef, show promise, but the 2024 Outlook Report emphasizes that climate change compromises recovery capacity. The GCRMN's call for data for the 2025 report indicates ongoing efforts to monitor and understand the extent of damage, but preliminary findings suggest the picture is grim.

Summary of Causes and Impacts

To organize the causes and their impacts, the following table summarizes the key factors and their effects on coral reef health:

Cause	Impact on Coral Reefs
Climate Change (Warming)	Causes bleaching, increases mortality, reduces recovery potential.
Climate Change (Acidification)	Dissolves coral skeletons, hinders growth, reduces biodiversity.
Overfishing	Disrupts ecosystem balance, reduces fish that control algae, affects fisheries.
Pollution	Degrades water quality, stresses corals, increases disease susceptibility.
Coastal Development	Increases sedimentation, blocks sunlight, causes physical damage.
Diseases	Spreads rapidly, causes mortality, particularly in stressed reefs.

This table highlights the multifaceted nature of the threats, with climate change as the overarching driver and local factors amplifying the decline.

Conclusion
In conclusion, coral reefs are declining globally, with research suggesting over 50% loss since 1957 and recent bleaching events affecting over 80% of reefs. The evidence leans toward climate change, particularly ocean warming and acidification, as the main cause, with local factors like overfishing, pollution, and coastal development adding significant pressures. Addressing this decline requires urgent global action to reduce emissions and local efforts to mitigate human impacts, though the outlook remains challenging given the scale and speed of current changes.

Key Citations

- EPA Threats to Coral Reefs
- UNEP Why are Coral Reefs Dying
- NASA Vanishing Corals Data Tracking
- Natural History Museum Coral Reef Cover Loss
- IUCN Red List Coral Species Extinction
- The Guardian Coral Reef Bleaching Crisis
- WHC Great Barrier Reef Recovery
- USFWS Great Barrier Reef Outlook Report
- ScienceDaily Coral Reefs News Updates
- EPA US Coral Reefs Initiatives
- GCRMN 2025 Report Call for Data
- Coral Reef Alliance State of Reef Report

18 web pages

2 3 4

Deep Search

Ask anything

Generate image

From: judith curry <curry.judith@gmail.com>
Sent: Thursday, May 22, 2025 2:17 PM
To: Ross McKitrick
Cc: Roy W. Spencer; John Christy; Steven Koonin; Travis Fisher
Subject: Re: PDF version 11:30 AM

I just read the collated doc and send not to include any of the changes discussed in our wed call at least for my chapters

Sent from my iPhone

> On May 22, 2025, at 8:30 AM, Ross McKitrick <ross.mckitrick@gmail.com> wrote:

>

>

> I have to head out to do a few things so I'm going to call a halt to the fine-tuning process. I'm attaching a Word version and PDF of the compiled and formatted report draft that contains everything up to and including John's email at 11:26. I think it is a good first draft for the Secretary to read this afternoon.

>

> Lists of chapter references will need considerable wrangling in some places, which I will help with over the next couple of days.

>

> I need to think about how to handle further revisions over the coming days so we maintain version control. Until I get back to you, make notes of any fixes that are needed but don't email them bc I will probably lose them.

>

>

>

> <Report Draft May 22[RM.1130AM].docx>

> <Report Draft May 22[RM.1130AM].pdf>